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SURVEY AND SCREENING BACTERIAL PATHOGENS FOR CANADA THISTLE IN SASKATCHEWAN AND FROM CENTRE OF WEED ORIGIN

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PROJECT TITLE: Survey and Screening Bacterial Pathogens for Canada Thistle in Saskatchewan and from Centre of Weed Origin

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ABSTRACT/SUMMARY

The objective of this project was to evaluate strains of bacteria that are i) indigenous to Saskatchewan and ii) foreign isolates collected from the centre or origin of Canada thistle (southeastern Europe area) for potential as biological control agents of Canada thistle. Canada thistle plants exhibiting apical chlorosis symptoms were collected and bacteria isolated and purified from the diseased plant material and evaluated for biocontrol potential. Two methods, a root dip/soil drench method and wounding inoculation method, provided effective methods for screening for bacteria whereas a callus tissue culture method did not discriminate between highly promising bacterial strains and those which do not have much biocontrol potential. In year 1, a total of 9 bacterial strains (VA02-14, VA02-22, WE02-1, WE02-3, FE02-7, FE02-8, FE02-9, FE02-10, and WE02-21) either reduced growth rate of Canada thistle or showed symptoms on the weed. During the second year of screening, an additional 30 strains either reduced growth rate or biomass of Canada thistle; only 2 bacterial strains (GOT-03-4 and BIELF1-03 -8) had effects using both the meristem inoculation method and the root dip method. Further validation of the screening methods and any modifications required to the screening was conducted. It was determined that an airbrush method using a formulation (Silwet L77) was required and that a second indicator plant, sunflower, could provide more consistent and reliable results than testing with Canada thistle alone, which has a variable growth habitat and possesses several biotype populations. Re-screening some bacteria revealed that strains WE02-3 and FE02-8 showed promising results; an additional 12 bacterial strains from Europe were also further selected as potential biocontrol agents for future evaluation. This project will greatly increase the probability of finding new strains of bacteria, including more improved strains of PST for bioherbicide development in Saskatchewan.

EXECUTIVE SUMMARY

Canada thistle is one of the targeted weeds for inundative biological control in the Weed Biocontrol program at Saskatoon. A phytopathogenic bacterial agent causing apical chlorosis, *Pseudomonas syringae* pv. *tagetis* (PST), has been under investigation (Johnson & Wyse, 1991). It also causes stunting and necrosis in other composite weeds, mainly due to the production of a toxin (= tagetitoxin). Symptoms are only expressed when the bacterium is applied with a special formulation and application with sub-lethal rates of glyphosate can improve control of Canada thistle (Bailey et al. 2000). However, research at Saskatoon has revealed that there is inconsistent field performance of PST under variable weather conditions (Boyetchko, unpublished data). The proposed project is an enhancement of our on-going efforts to identify biocontrol agents Canada thistle in Saskatchewan, and will complement our current research efforts by increasing the chance of finding the most efficacious organisms through the search in areas of the weed origin. Positive outcomes may lead to development of biological products with participation of industry. Concurrent evaluation of indigenous and foreign isolates can save time considerably.

The proposed project will evaluate additional strains of bacteria that are i) indigenous to Saskatchewan and ii) foreign isolates collected from the centre of origin of Canada thistle (southeastern Europe). Field surveys were conducted in southeastern parts of Europe during the growing season. Canada thistle exhibiting apical chlorosis symptoms was collected and bacteria isolated and purified from the diseased plant material and evaluated for biocontrol potential. The

project can greatly increase the probability of finding new strains of bacteria, including more improved strains of PSTfor product development in Saskatchewan.

A total of 105 indigenous (Canadian) bacterial strains were isolated from Canada thistle plants and screened using a callus tissue culture method; 82 of these strains ranked a rating of 4 or higher (out of a maximum of 5) for symptoms. From the foreign (European) isolates, 27 out of 50 strains rated 4 or higher. In addition, a total of 117 European bacterial strains and 6 indigenous strains (Canadian) underwent two additional screening methods: a root dip/soil drench method and wound inoculation method.

In year 1, a total of 9 bacterial strains (VA02-14, VA02-22, WE02-1, WE02-3, FE02-7, FE02-8, FE02-9, FE02-10, and WE02-21) either reduced growth rate of Canada thistle or showed symptoms on the weed. In year 2, a total of 6 indigenous and 67 bacterial strains were screened using the meristem wounding method and the root dip/soil drench method only. PST EB056 showed more consistent symptoms and reductions in shoot growth and biomass using the meristem wounding inoculation method, compared to the root dip and soil drench method. Two bacterial strains from Saskatchewan and 10 from Europe showed chlorosis-type symptoms. Seven European bacterial strains reduced shoot growth rates; 3 indigenous (Saskatchewan) strains and 1 European strain reduced biomass. For the root dip and soil drench method, 5 European strains exhibited chlorosis type symptoms; 8 European strains reduced shoot growth rate and only 1 indigenous and 7 European strains reduced biomass of Canada thistle. The bacterial strains that had consistent effect using both the meristem wounding inoculation method and the root dip/soil drench method were GOT-03-4 and BIELF1-03-8. Also, chlorosis symptoms were not consistently correlated with the ability of the bacteria to reduce shoot growth rate and biomass of Canada thistle. Therefore, symptoms alone may not necessarily be good indicators of the pathogenicity and potential bioherbicidal activity of the bacterial strains.

One of the biggest challenges in the project was the selection of a suitable screening method. For example, after the first year of the project, we concluded that the callus tissue culture screening method does not provide an effective screening tool since it cannot discriminate between those bacteria that have biocontrol potential (i.e. by reducing growth of Canada thistle) and those bacteria that simply cause some necrosis on the callus tissue culture. Also, we did not get consistent expression of symptoms and fresh weight reductions on Canada thistle, so we included testing on other indicator plants such as sunflower and marigold, which belong to the same Asteraceae family as Canada thistle. In other studies using PST, sunflower has been used as an indicator plant and marigold is one of the plants from which PST which originally isolated and described. The Canada thistle plant is also a genetically diverse weed with variable growth habit and several biotypes, which in part have an effect on selection of a reliable screening method.

Further validation of the screening method resulted in the selection of an airbrush method using the surfactant Silwet L77 to facilitate entry and infection by the bacteria. In addition, sunflower has also been included in the screening program because it has similar susceptibilities to the bacteria, including PST, as Canada thistle and it has more uniform growth habits. An additional 143 bacterial strains were shipped from Europe by Dr. Andre Gassmann in January 2005 and screened for biocontrol potential using the airbrush method and 12 of these bacterial strains have been further selected for future evaluation.

Literature Cited

Bailey, K.L., S.M. Boyetchko, J. Derby, W. Hall, K. Sawchyn, T. Nelson, and D.R. Johnson. 2000. Evaluation of fungal and bacterial agents for biological control of Canada thistle. Pages 203-208 In: Proc. X International Symposium on Biological Control of Weeds, 4-14 July, 1999, Montana State Univ., Bozeman, Montana, N.R. Spencer (ed.)

Johnson, D.R., and D.L. Wyse. 1991. Use of *Pseudomonas syringae* pv. *tagetis* for control of Canada thistle (*Cirsium arvense*). Proc. North Central Weed Sci. Soc. 46:14.

Moore, R.J. 1975. The biology of Canadian weeds. 13. *Cirsium arvense* (L.) Scop. Can. J. Plant Sci. 55:1033-1048.

TECHNICAL REPORT

Objectives of Project

The main objectives of this research project are to:

i) Survey for new strains of bacteria (indigenous and foreign) from Canada thistle showing apical chlorosis;
ii) Screen purified bacterial strains using callus tissue culture and whole-plant screening method;
iii) Evaluate the efficacy, disease-causing ability and bioherbicidal potential of leading bacterial candidates for control of Canada thistle.

Background and Rationale

Canada thistle is an economically important perennial weed found in all provinces of Canada (Moore, 1975). It is the second most important weed in field crops and approximately 9 million hectares of cultivated land in the three prairie provinces are infested with this weed, with annual losses estimated at more than $320 million. Canada thistle has become a greater problem under reduced tillage, coupled with increased production of broad-leaf specialty crops such as lentil, chickpea, pea, and seed alfalfa, where certain herbicides cannot be used.

Canada thistle is one of the targeted weeds for inundative biological control in the Weed Biocontrol program at Saskatoon. A phytopathogenic bacterial agent causing apical chlorosis is *Pseudomonas syringae* pv. *tagetis* (PST) (Johnson & Wyse, 1991) has been under investigation. It also causes stunting and necrosis in other composite weeds, mainly due to the production of a toxin (= tagetitoxin). Symptoms are only expressed when the bacterium is applied with a special formulation and application with sub-lethal rates of glyphosate can improve control of Canada thistle (Bailey et al. 2000). However, research at Saskatoon (Boyetchko, unpublished data) has revealed that there is inconsistent field performance of PST under variable weather conditions.

The proposed project will evaluate additional strains of bacteria that are i) indigenous to Saskatchewan and ii) foreign isolates collected from the centre of origin of Canada thistle (southeastern Europe and eastern Mediterranean area). Field surveys will be conducted in southeastern parts of Europe during two growing seasons. Canada thistle exhibiting apical chlorosis symptoms will be collected and bacteria isolated and purified from the diseased plant material and evaluated for biocontrol potential. The project can greatly increase the probability of finding new strains of bacteria, including more improved strains of PSTfor product development in Saskatchewan.

Bailey, K.L., S.M. Boyetchko, J. Derby, W. Hall, K. Sawchyn, T. Nelson, and D.R. Johnson. 2000. Evaluation of fungal and bacterial agents for biological control of Canada thistle. Pages 203-208 In: Proc. X International Symposium on Biological Control of Weeds, 4-14 July, 1999, Montana State Univ., Bozeman, Montana, N.R. Spencer (ed.)

Johnson, D.R., and D.L. Wyse. 1991. Use of *Pseudomonas syringae* pv. *tagetis* for control of Canada thistle (*Cirsium arvense*). Proc. North Central Weed Sci. Soc. 46:14.

Moore, R.J. 1975. The biology of Canadian weeds. 13. *Cirsium arvense* (L.) Scop. Can. J. Plant Sci. 55:1033-1048.

Experimental protocols

A. Isolation and purification of bacteria from Canada thistle

Canada thistle plants exhibiting apical chlorosis symptoms were collected from western Canada (mostly Saskatchewan and Alberta) and from surveys conducted in Europe (see **Appendices A1 and A2**; Germany, Switzerland; France; and Serbia). Diseased plant material was surfaced sterilized in 0.5% sodium hypochlorite (10% bleach) for 5 minutes and rinsed 2-3 times in sterile distilled water for 5 minutes each time. Plant material was placed in a mortar and pestle with sterile phosphate buffer and serial diluted. The resulting suspension were spread onto agar plates (e.g. Pseudomonas agar F) in 0.1 ml aliquots, incubated at room temperature, and individual colonies randomly selected and purified until purity of each bacterial was ensured. Bacteria were stored at -70 C until further testing was conducted. All treatments included a non-bacterial inoculated plant, and a strain of *Pseudomonas syringae* pv. *tagetis* (PST - EB056) as a positive control.

B. Screening methods

i) Callus tissue culture screening method

Canada thistle tissue culture was generated from root tissues that were grown on tissue culture media according to Schenk and Hildebrandt (Schenk, R.U., and A.C. Hildebrandt, 1972. Medium and techniques for induction and growth of monocotyledonous and dicotyledonous plant cell cultures. Can. J. Bot. 50:199-204). Callus culture was maintained on this media and 3 pieces of callus per plate per bacterial strain were placed onto culture media for screening.

Purified bacteria isolated from Canada thistle were grown on Pseudomonas Agar F, individual colonies added to 20 ml of nutrient broth and incubated for 48 hours on a rotary shaker at 150 rpm. For each bacterial strain, 20 µl of the resulting bacterial culture was placed on each piece of callus tissue (3 callus pieces per plate), incubated for approximately 5 dates, and disease ratings conducted. Bacterial strains demonstrating a rating of 4 or higher (over the average of 3 callus tissues) were considered for further evaluation.

Rating scale used was as follows:

0 = Control (healthy looking green callus)
1 = spots of brown (>80% green tissue)
2 = off-green color (40-80% green tissue)
3 = slightly tan color (some "clumps of green")
4 = light brown (no green)
5 = completely dead – dark brown (no green color)

ii) Root dip and soil drench screening method

Cultures of bacterial strains stored in 20% glycerol in the -70°C ultra-low freezer were transferred to Pseudomanas Agar-F (PAF) plates and incubated for 5 to7 days at 20°C. Isolated colonies were inoculated into 15 ml of nutrient broth in 50 ml centrifuge tubes. After incubation at 20°C for 48 hours on a rotary shaker at 150 rpm, the bacterial suspension was used as the seed culture for all treatments.

For each bacterial strain treatment, 250 ml aliquots of media (e.g. nutrient broth) were prepared (and autoclaved) and aseptically dispensed into 500 ml baffled erlenmeyer flasks. For each treatment, flasks were inoculated with 100 µl of a 48 hour bacterial culture suspension. An uninoculated flask of liquid broth was used as the control. The bacterial cultures were incubated at 20°C at 150 rpm for 48 hours.

Inoculation of Canada thistle: From the above bacterial suspensions, Canada thistle root pieces (containing at least 1-2 buds) were placed into the bacterial suspension and on a shaker at 150 rpm for 10-15 minutes. Inoculated root pieces (1-3 pieces per pot - keep the total number of buds the same among replicates) were sown into 4 -inch pots containing soil mix. In addition, approximately 25 ml of the bacterial suspension was added into each of the pots as a soil drench and placed in the greenhouse. The experiment consisted of 5 pots (reps) containing one Canada thistle plant per pot. Plant growth (e.g. shoot emergence, biomass) and disease symptoms were recorded (2, 4 and 6 weeks after inoculation) and biomass data was collected.

iii) Wounding inoculation method

Bacterial agents were grown as described above (B ii). Scissors were sterilized by dipping into ethanol and then flaming. Sterilized scissors were placed into bacterial suspension and subsequently used to cut the top of Canada thistle plants (14 day-old seedlings; approximately 4-6 inches tall). Also, 2-3 ml of bacterial suspension was added by pipetting over the wound of the Canada thistle plant in order to ensure that adequate inoculum was delivered to the plant. The

experiment was replicated 5 times.

C. Validation of screening methods and confirmation of leading bacterial strains

The utility and reliability of both screening methods, root dip/soil drench and wounding inoculation method, was further validated. The reason for this is that the expression of disease symptoms and fresh weight reductions were often inconsistent on Canada thistle with the inoculation of the bacteria, including PST (original strain EB056). We decided to include sunflower and marigold as 2 additional indicator plants, since sunflower has been used as an indicator for the PST strain, while marigold is considered one of the original hosts for PST where it was isolated and described (i.e. "tagetis", genus for marigold). We also decided to i) compare another inoculation method utilizing an organosilicone surfactant as a formulation (Silwet L77) at different concentrations; ii) re-test the pathogenicity of the PST and compare it to a PST isolate that we re infected with marigold and re-isolated from highly diseased plants; iii) determine optimum concentration of PST required to get marginal disease symptoms and fresh weight reductions on the various indicator plants; and iv) select one methodology and re-test the leading bacterial strains we obtained from this study and rank the most promising strains.

i) Comparison of 3 inoculation methods and 3 indicator plants

Three inoculation methods were compared: meristem (stabbing) inoculation method, wounding inoculation (method already outlined in section Biii) and airbrush method using Silwet L77 as a surfactant. For the meristem (stab) method, an inoculation needle containing a loopful of PST colony obtained from agar plates was stabbed into the meristem of the plants (at the apex between the top leaves). For the airbrush method, the PST was grown in liquid culture at 20°C at 150 rpm for 48 hours as outlined in Bii. After 48 hours, the PST reached a concentration of 1 X 10^8 colony-forming units (cfu) per ml. The bacteria were suspended in Silwet L77 at different concentrations (0.1%, 0.15%, and 0.3%) and applied with an airbrush at 15 psi using 20 ml of bacterial/Silwet suspension per four pots. The 3 indicator plants used were sunflower, marigold, and Canada thistle (stage of application was 4-6 inches tall). Disease ratings (see section E) were taken 1, 2, and 3 weeks after application (for all methods) using the 0-5 rating scale and fresh weights were determined after 3 weeks.

ii) Pathogenicity of PST

Due to inconsistency of symptoms expressed by PST on Canada thistle in previous experiments, we were not sure if the PST strain we were using had lost its pathogenicity. In order to determine if pathogenicity was maintained, we inoculated the PST onto marigold plants, re-isolated the bacteria from diseased material, and confirmed the identity of the PST that it was the same as the bacteria that was inoculated onto the plants. We then compared the pathogenicity of this re-isolated strain to the original PST (EB056 strain) obtained from Encore Technologies in Minnesota. The PST was grown as outlined above and applied with Silwet L77 (0.15% and 0.2%, v/v). These two PST strains were compared for symptoms (1, 2, and 3 weeks after application) and fresh weights on the 3 indicator plants (sunflower, marigold, and Canada thistle).

iii) Concentration effects of PST

We compared the effect of several concentrations of PST on symptoms and fresh weights of sunflower, marigold, and Canada thistle. The PST was grown for 48 hours as outlined above, and reached a final concentration of 1 X 10^8 cfu per ml (or 1X conc.). This concentration was then adjusted to 0.1X, 0.5X, 1X and 2X in Silwet L77 (0.2%, v/v) and applied using an airbrush method. Disease symptoms and fresh weights were measured as described earlier.

iv) Validation of Biocontrol potential of Bacterial Strains

Some of the top leading bacterial strains selected for further testing in year 1 and year 2 were validated using the airbrush application method using 0.2% Silwet as a formulation and including sunflower and Canada thistle as the indicator plants. Fresh weights and disease symptoms were determined and the bacterial strains were ranked according to their bioherbicidal potential.

D. Growth of inoculated plants in greenhouse

All treated plants were kept in a growth chamber at 20°C and a 16 h photoperiod. Plants were watered with distilled water, since tap water is chlorinated and can kill bacterial agents.

E. Data collection and statistical analysis

For the root dip/soil drench method and wounding method, shoot length measurements (mm) were taken after 2, 4, and 6 weeks and relative growth rates calculated between 2 and 4 weeks and 4 and 6 weeks. Relative growth rates were calculated as follows:

$$\frac{\text{(Shoot height at 4 weeks – Shoot height at 2 weeks)}}{\text{Shoot height at 2 weeks}} \times 100$$

Disease symptoms were also recorded according to the following disease rating scale:

0 = healthy
1 = stunting with no detectable chlorosis
2 = detectable chlorosis
3 = moderate chlorosis
4 = severe chlorosis and some necrosis
5 = severe chlorosis and necrosis

All data were subjected to statistical analysis by the Statistical Analysis System (SAS) using the analysis of variance (ANOVA) using General Linear Model (Proc GLM) procedure, and treatment means were separated using Least Significant Difference (LSD) test (P=0.05).

Results and Discussion

A. Surveying

Canada thistle plants exhibiting apical chlorosis symptoms on Canada thistle were collected from various parts of Europe (Germany, Switzerland, France, and Serbia) and Saskatchewan (see **Appendices A1 and A2**). Bacteria were isolated and purified from diseased plants and used for screening their potential as biocontrol agents. An additional 111 bacterial strains were isolated and purified from these plants in the laboratory in Delemont, Switzerland and shipped to Saskatoon in January 2005. These were further grown on selective media, ensured for purity, and placed in the ultra-low freezer at -70°C and screened from April - June 2005. Leading bacterial strains were selected.

B. Screening

Year 1

A total of 105 indigenous (Canadian) bacterial strains were screen using a callus tissue culture method. In addition, 117 European bacterial strains and 6 indigenous strains underwent two additional screening methods: a root dip/soil drench method and a wound inoculation method. Results on effects on shoot growth rate and biomass, and disease symptoms are provided in **Tables 1 and 2** and in **Appendices A1, A2, and B**.

Year 2

A total of 6 indigenous bacterial strains from Saskatchewan and 67 from Europe were selected for screening using two methods: meristem wounding inoculation method and root dip/soil drench method. Results for each method are presented below and data on effects on shoot growth rate and biomass, and disease symptoms are provided in **Tables 3-6**.

i) Callus tissue culture screening method

Canada thistle plants exhibiting apical chlorosis were collected from various sites in Saskatchewan and Alberta. Also, some bacteria were obtained from the existing microbial culture collection at AAFC, Saskatoon and included in the screening. A total of 155 bacterial strains (105 indigenous to Saskatchewan and the Canadian prairies and 50 foreign isolates from Europe) were tested using the callus tissue culture method (see **Appendix A1** for the list of bacterial strains). From the indigenous (Canadian) isolates, 82 out of 105 bacterial strains (78% of the bacteria tested) ranked a rating of 4 or higher, out of a maximum rating of 5. These bacteria will be further evaluated in the whole plant (root dip/soil drench method and wounding method). From the foreign (European) isolates, 27 out of 50 (54% of the strains) rated 4 or higher.

ii) Meristem wounding inoculation method

Year 1

Using the meristem wounding inoculation method, 7 bacterial strains (in addition to the

PST strain) showed either showed significant reduction in growth rate and/or disease symptom expression, when compared to the untreated control plants (**Table 1**). Actual shoot length measurements are provided in **Appendix B** and shoot growth reductions are calculated accordingly. Strain WE02-3 showed reductions in growth rate, strain WE02-1 reduced total biomass, strain VA02-14 showed significant disease expression (40% of plants showed chlorosis) (see **Appendix C** for photographs showing symptoms), while strain WE02-21 reduced growth rate and showed significant disease symptoms (40% of plants showed symptoms). Three additional strains (FE02-5, FE02-6, and FE02-7) expressed some symptoms, although not significant compared to the untreated control plants. Strain PST only showed symptoms but did not reduce growth rate or biomass of Canada thistle using this screening method.

Year 2

The results for the meristem wounding inoculation method are provided in **Table 3** (effect on shoot growth rate and biomass) and **Table 5** (disease symptoms). Results where bacterial treated plants showed significant reductions compared to untreated controls are highlighted in yellow.

In 15 out of 17 experiments, Canada thistle plants inoculated with PST EB056 (the positive control) exhibited some type of chlorosis, which is typical of the apical chlorosis for this bacterial agent (**Table 5**). However, not all plants showed these symptoms (20 - 80% of plants per treatment), indicating the lack of consistent effects by PST. After 2 weeks, plants inoculated with bacterial strains 98-75CT4 and CTB12 exhibited very slight chlorosis on a significant number of plants (**Table 3**). Other bacterial strains (98-75CT7, UH2-03-5, BIELF1-03-10, SIE1-03-4, SIE1-03-7, URC2-03-7, URC3-03-3, URC3-03-5, UGR-03-6, WRE-03-18, and UH2-03-14) exhibited very slight chlorosis once during the six week period; however, the number of plants that were affected was not significant.

When examining the effect on shoot growth rate reductions (**Table 3**), PST EB056 and GOT-03-6 significantly reduced growth rate between 2 and 4 weeks compared to the untreated control (in Experiment 17). In Experiment 15, the growth rate reductions measured after 2-4 and 4-6 weeks were significantly lower for plants inoculated with BIELF3-03-15. Also, growth rate reductions during the 4-6 week period were significantly reduced with bacterial strains PST EB056 and BIELF1-03-8 (Experiment 15). In other experiments (e.g. Experiments 5, 7, and 15), growth rate reductions (4-6 week period) were lower in plants inoculated with PST EB056, BIELF3-03-6, BIELF3-03-8, BIELF3-03-10, BIELF1-03-1, BIELF2-03-5, and FR-03-2) when compared to the untreated controls. For total biomass reductions, significant reductions were observed with bacterial strains with SIO1-03-4, PSTEB056, 98-75CT398-75CT4, 98-75CT7 and CTB12.

iii) Root dip and soil drench screening method

Year 1

Using the root dip and soil drench method, 5 bacterial strains (in addition to the PST strain) showed significant reduction in growth rate compared to the untreated control plants

(**Table 2**). Actual shoot length measurements are provided in Appendix B and shoot growth reductions are calculated accordingly. Strains VA02-22, FE02-7, FE02-8, FE02-9, and FE02-10 reduced growth rate of Canada thistle, but showed not symptom expression. Strain PST (known to have some ability to control Canada thistle) did show some significant reductions in growth rate and showed symptoms, but this was not consistently expressed when repeated in some of the various experiments.

Year 2

The results for the root dip and soil drench method are provided in **Table 4** (effect on shoot growth rate and biomass) and **Table 6** (disease symptoms). Results where bacterial treated plants showed significant reductions compared to untreated controls are highlighted in yellow.

Using this screening method, inoculation of Canada thistle plants with PST EB056 exhibited apical chlorosis symptoms, but the results were not as consistent (only 7 of the 17 experiments testing this bacterial strain, the positive control) as the meristem inoculation method. Other bacterial strains which did cause symptoms of chlorosis after 2 weeks were KIR-03-1, URC3-03-3, URC4-03-3 and UH2-03-6 (**Table 6**), but the bacteria did not affect a significant number of plants. Plants treated with ESP-03-7 exhibited chlorosis at 6 weeks (not at 2 or 4 weeks); however the chlorosis was very slight and it didn't affect a significant number of plants.

In experiment 5, the growth rate of Canada thistle from 2 to 4 weeks was significantly lower for bacterial strains BIELF1-03-6, BIELF1-03-8, BIELF1-03-10, and PSTEB056 compared to the untreated control (**Table 4**). Also, in Experiment 14, the 2 to 4 week growth rate of Canada thistle was significantly lower when inoculated with bacterial strains UH2-03-13, UH2-03-14, UH2-03-15, compared to the untreated control. Bacterial strain URC2-03-2 caused a significant reduction in growth rate from 4 to 6 weeks (experiment 10), while BIELF2-03-7 and PSTEB056 caused significant reductions in the 4 to 6 week growth rate compared to the control.

In three experiments, the plants treated with PST EB056 had significantly lower shoot biomasses than the untreated control plants. Plants inoculated with bacterial strains 96-5-Su6-1-C6I2, DOB1-03-1, DOB2-03-5, DOB2-03-1, URC2-03-3, WRE-03-12, WRE-03-14, WRE-03-18 and WRE-03-19 also had significantly lower shoot biomasses compared with the control in their respective experiments.

C. Validation of screening methods and confirmation of leading bacterial strains

i) Comparison of 3 inoculation methods and 3 indicator plants

Results are presented in Tables **7-10**. The application of PST in 0.3% Silwet caused significant reduction in fresh weight of sunflower using all methods, while only the airbrush method caused reductions in fresh weight of marigold (**Table 7a**). None of the methods caused reductions in fresh weight of Canada thistle. The expression of disease symptoms were far superior for all indicator plants using the airbrush method (**Table 7b**) where symptoms reach 4 out of a maximum rating of 5. The meristem and wounding method did not cause great levels of disease symptoms on all the indicator plants (only minimal apical chlorosis was observed). In the

untreated control, no symptoms were observed, but some initial phytotoxicity from the Silwet at a concentration of 0.3% (v/v) was observed. Therefore, we repeated the same experiment above, but using 0.1% Silwet (**Tables 8a, 8b, 9a, 9b** - experiment conducted twice). Fresh weight reductions of sunflower were observed using the meristem (stab) and airbrush method, but not the wounding method, while for marigold, fresh weights were reduced using all methods, with the airbrush method being the best (**Table 8a**). None of the methods caused fresh weight reductions on Canada thistle. A repeat of this experiment showed similar results for sunflower (**Table 10a**), but none of the methods for marigold and Canada thistle reduced fresh weights. This indicates that using a lower concentration of Silwet (0.1%) is not adequate to obtain fresh weight reductions. Disease symptoms using all the methods for all the indicator plants were not as dramatic as using a 0.3% concentration of Silwet (**Tables 8b and 9b**). If we increased the concentration of Silwet to 0.15%, the results for fresh weight reductions and disease symptoms were similar when 0.1% Silwet concentration was used (**Tables 10a and 10b**).

Therefore, in order to alleviate the phytotoxicity effects of the Silwet at the higher concentration of 0.3%, we chose to use a concentration of 0.2% concentration for subsequent experiments. In addition, it is recommended that using the inoculation of PST and other bacteria using the airbrush provides a more reliable method for screening bacteria against Canada thistle. It is known that foliar applied bacteria require either wounds or natural openings (such as stomata) to cause disease in plants. The adjuvant Silwet L77 is an organosilicone surfactant that reduces the surface tension of spray droplets containing the bacteria and draws the bacteria under the leaf surface into the stomata. This subsequently provides a means of entry for the bacteria to cause disease symptoms.

ii) Pathogenicity of PST

From the experiments comparing screening methods and indicator plants, unfortunately, the PST did not cause significant fresh weight reductions in Canada thistle, while sunflower and marigold fresh weights were highly affected, especially using the airbrush method. Therefore, we conducted further pathogenicity tests to determine if our PST strain mutated and did not have high pathogenicity to the Canada thistle. We compared the original PST strain (freezer PST) obtained from Encore Technologies to the PST strain that we re-infected onto marigold plants (fresh PST) and tried to restore the pathogenicity (see results in **Tables 11a, 11b, 12a, and 12b**). We used Silwet at a concentration of 0.2% in the first experiment, and 0.15% in the second. Both PST strains reduced fresh weights in sunflower and marigold compared to the untreated control and Silwet alone (without PST) using Silwet at 0.2% and 0.15% concentrations (**Tables 11a and 12a**). However, there was no signficant reduction to fresh weights of Canada thistle with the PST, even compared to the untreated and Silwet controls. Disease symptoms were very good with both bacterial strains (**Tables 11b and 12b**), with minor phytotoxicity occurring with 0.2% Silwet. These results demonstrated that the pathogenicity of the PST strain was not changed and the results indicated to us that Canada thistle may be a more complex plant than domesticated sunflower and marigold and not a good indicator plant for fresh weight reductions in the early stages for screening bacteria for a bioherbicidal effect. This may in part be due to the genetic make-up of the Canada thistle plant which is a very heterogeneous populations where several biotypes of the weed are known to exist. On the other hand, sunflower and marigold are bred for genetic uniformity and may act as more reliable and consistent indicator plants for screening.

iii) Concentration effects of PST

To further determine if we could enhance disease symptoms and fresh weight reductions of PST on Canada thistle, we tested different concentrations of PST. We applied the PST using the airbrush method using Silwet at a concentration of 0.2% (v/v) (see **Tables 13a, 13b, 14a, and 14b**). There was significant fresh weight reductions of sunflower and marigold, particularly at the 1X concentration (**Tables 13a and 14a**) and disease symptoms were expressed with these treatments. However, there was no fresh weight reduction of Canada thistle at any of the application concentrations of PST. This validates our assumption that there may be problems in screening the bacteria, including PST, on Canada thistle at the early screening stages. It appears that Canada thistle itself is a very complex perennial weed, that is genetically diverse and there may be several biotype populations. Some work being conducted with the USDA/ARS in Sydney, Montana by a molecular taxonomist is demonstrating that even within the Canadian prairies, there are several populations of Canada thistle (John Gaskin, personal communication to S. Boyetchko - unpublished data). We provided samples of some of our Canada thistle populations obtained within our research plots at Saskatoon, and from Canada thistle collected throughout Saskatchewan and Alberta. These Canada thistle populations appear to be genetically diverse.

iv) Validation of Biocontrol potential of Bacterial Strains

Results are presented in **Tables 15a and 15b**. Out of the bacterial strains that were selected for further validation, 3 bacterial strains (FE02-8, WE02-3, and PST) were the top candidates that reduced fresh weights of sunflower (**Table 15a**). However, none of the bacterial strains reduced fresh weights of Canada thistle significantly despite the fact that PST-treated plants were 20% lighter. There was also too much variabililty in the growth of Canada thistle (even in the untreated controls), suggesting the need for a reliable indicator plant with more uniform growth. The only bacterial strain that showed pronounced or visible symptoms of apical chlorosis was PST (**Table 15b**) for both sunflower and Canada thistle. The results here confirm that we may be able to use sunflower as an indicator plant for plant fresh weight reductions, but that disease symptoms may not always be associated with fresh weight (biomass) reductions. Also, we need to include Silwet (concentration of 0.2%, v/v) and the airbrush method for screening the bacteri, particularly because the bacteria require a method of entry into the plant in order to cause infection/disease.

As a result of our decision to select the airbrush method using Silwet L77 at a concentration of 0.2% for screening bacteria against Canada thistle, and to include sunflower as an indicator plant, an additional 143 bacterial strains obtained from surveys in Europe were screened for biocontrol potential. Out of these, 12 additional bacterial strains significantly reduced fresh weights and were selected for continued testing.

Conclusions:

A. Screening

Year 1

A total of 9 bacterial strains (VA02-14, VA02-22, WE02-1, WE02-3, FE02-7, FE02-8, FE02-9, FE02-10, and WE02-21) either reduced growth rate of Canada thistle or showed symptoms (e.g. chlorosis) on the weed, or both, using either the root dip/soil drench or the wounding inoculation method. Three additional bacterial strains showed some symptoms, but it was sometimes difficult to distinguish whether these symptoms were also a function of the natural senescence of the weed or were symptoms related to other physiological processes. It appears that disease expression is not necessarily an appropriate indicator of the biocontrol potential of some of the bacterial strains because some of the bacteria will reduce the growth of Canada thistle without exhibiting disease symptoms.

The callus tissue culture method did not discriminate superior bacterial strains with biocontrol activity from those with mediocre biocontrol activity, particularly when comparing the effects of the European strains using the callus tissue culture method to the results obtained using the root dip/soil drench and wounding inoculation method with these same strains. In addition, more than 50% of the European and indigenous strains rated 4 or higher using this screening method which does not discriminate against highly effective bacterial strains. This tissue culture method appears to be more appropriate for use when studying detailed mode of action of the bacteria and is most likely not an effective screening tool for preliminary selection of bacterial strains.

Year 2

A total of 6 indigenous and 67 bacterial strains were screened using the meristem wounding inoculation method and the root dip/soil drench method only. PST EB056 showed more consistent symptoms and reductions in shoot growth and biomass using the meristem wounding inoculation method, compared to the root dip and soil drench method. Two bacterial strains from Saskatchewan and 10 from Europe showed chlorosis-type symptoms. Seven European bacterial strains reduced shoot growth rates; 3 indigenous (Saskatchewan) strains and 1 European strain reduced biomass.

For the root dip and soil drench method, 5 European strains exhibited chlorosis type symptoms; 8 European strains reduced shoot growth rate and only 1 indigenous and 7 European strains reduced biomass of Canada thistle. The bacterial strain that had consistent effect using both the meristem wounding inoculation method and the root dip/soil drench method was bacterial strain BIELF1-03-8. Also, chlorosis symptoms were not consistently correlated with the ability of the bacteria to reduce shoot growth rate and biomass of Canada thistle. Therefore, symptoms alone may not necessarily be good indicators of the pathogenicity and potential bioherbicidal activity of the bacterial strains.

B. Validation of screening and confirmation of leading bacterial strains

We validated the screening methods that we use to best select for promising bacterial strains against Canada thistle. Canada thistle is a very complex and genetically diverse weed that is known to possess many biotypes. It is a perennial weed that also exhibits great variability in its growth habits and may not often be a suitable indicator plant for preliminary screening for biocontrol agents, due to these traits. As a result, it was important to determine if there were other suitable indicator plants such as sunflower and marigold, which are also members of the Asteraceae (Compositae) and which show susceptibility to some of the pathogens such as PST. In addition, we needed to also validate the two screening methods (root dip/soil drench and wounding inoculation methods); we also included a third method using an airbrush and incorporating a surfactant that would facilitate entry of the bacteria into the plant in order to maximize infection by the bacteria, since bacteria require wounds or natural openings. Also, we observed that the pathogenicity of the bacterial strain PST EB056 can be restored by re-infecting onto Canada thistle, marigold, or sunflower, re-isolating the bacterial strain, and symptoms such as apical chlorosis are more pronounced following this procedure.

We determined that the most suitable screening method was to use the airbrush with the surfactant Silwet L77 at a concentration of 0.2%. In addition, we needed to select an indicator plant such as sunflower that had similar susceptibilities to PST and the other bacteria as Canada thistle. Sunflower is easy to grow and has a uniform growth habit, while growth of Canada thistle can be somewhat variable. Even though the pathogenicity of the PST did not change, we discovered that disease symptoms, even with this pathogen, were not often uniformly expressed, particularly in Canada thistle. However, reductions in fresh weights appeared to be a better indication of the biocontrol potential for these endophytic bacteria. Despite the fact that the bacteria used in our screening program were originally obtained from Canada thistle plants in Europe that exhibited apical chlorosis symptoms, many of the bacteria did not necessarily express chlorosis type symptoms on Canada thistle plants that are biotypes from western Canada. Whether this is a result of the differences in susceptibility of the various biotypes to the bacteria, the highly variable growth habit of the Canada thistle, or even the complex of microorganisms inhabiting the diseased plants, we cannot be certain.

Table 1: Effect of European bacterial strains on growth rate and biomass of Canada thistle and disease symptoms using a meristem wounding inoculation method.

Isolate name	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	% Shoots with disease symptoms	Disease Rating and symptoms	Mean total biomass per pot ±S.E.
Control	14.4 ± 4.1 A	16.6 ± 7.3 A	0 A	0	1.4 ± 0.1A
VA02-1	25.8 ± 25.8 A	11.2 ± 8.8 A	25 A	1:ap leaf brn	1.1 ± 0.3 A
VA02-2	9.8 ± 8.6 A	9.2 ± 4.6 A	20 A	1:ap leaf brn	1.0 ± 0.1 A
VA02-3	9.4 ± 5.9 A	3.2 ± 3.2 A	0 A	0	1.5 ± 0.5 A
VA02-4	29.6 ± 12.0 A	11.2 ± 3.1 A	6.6 A	1:a	2.1 ± 0.7 A
Control	38.4 ± 9.4 A	14.4 ± 8.5 A	0 A	0	1.6 ± 0.2 A
VA02-5	21.8 ± 5.7 A	10.6 ± 9.2 A	0 A	0	1.7 ± 0.2 A
VA02-9	51.6 ± 26.5 A	12.6 ± 7.1 A	10 A	1: slt chlor	1.9 ± 0.2 A
VA02-10	42.2 ± 16.6 A	0.8 ± 0.8 A	20 A	1: slt chlor.	1.6 ± 0.4 A
VA02-11	43.8 ± 11.0 A	0.4 ± 0.2 A	0 A	0	2.1 ± 0.2 A
VA02-13	49.4 ± 6.8 A	0.6 ± 0.2 A	0 A	0	2.3 ± 0.4 A
Control	12 ± 4.6 A	5.0 ± 2.1 AB	0 B	0	1.0 ± 0.2 A
Pst EB056	21.4 ± 13.7 A	9.6 ± 2.7 A	10 AB	2:chlor.	0.8 ± 0.2 A
VA02-14	5.6 ± 5.6 A	2.6 ± 1.7 B	40* A	1-3 chlor.	0.9 ± 0.1 A
VA02-15	1.8 ± 1.1 A	2.6 ± 1.6 B	0 B	0	0.8 ± 0.1 A
	-	-	-	-	-
Control	27.0 ± 9.9	9.2 ± 1.8	0	0	1.5 ± 0.3
VA02-16	61.6 ± 19.3	8.4 ± 4.4	6.6	1:brn.died	2.5 ± 0.3
VA02-17	47.2 ± 11.8	2.4 ± 2.4	0	0	2.2 ± 0.1
VA02-22	28.2 ± 7.1	2.2 ± 1.4	8.0	1:chlor	1.9 ± 0.2
WE02-5	38.4 ± 11.0	3.0 ± 1.5	6.6	1:chlor	2.2 ± 0.2
WE02-13	27.4 ± 4.4	17.6 ± 2.3	0	0	1.5 ± 0.5
WE02-14	44.4 ± 9.3	6.8 ± 3.3	0	0	2.2 ± 0.3
Control	26.2 ± 5.0 AB	29.2 ± 18.5 A	5 A	2:chlor?	1.9 ± 0.5 A
VA02-18	22.6 ± 7.6 AB	12.6 ± 8.1 A	0 A	0	2.4 ± 0.5 A
VA02-19	36.8 ± 7.5 A	3.6 ± 1.5 A	0 A	0	1.7 ± 0.4 A
VA02-20	23.2 ± 9.1 AB	16.6 ± 7.2 A	0 A	0	1.9 ± 0.2 A
VA02-21	12 ± 3.8 B	11 ± 6.1 A	0 A	0	2.2 ± 0.2 A
VA02-22	-	-	-	-	-
Control	27.6 ± 12.9 A	1.2 ± 1.2 B	0 A	0	2.9 ± 0.4 A
WE02-1	12 ± 3.6 AB	2.6 ± 1.6 AB	20 A	1: browning	2.2* ± 0.2 B
WE02-2	7.2 ± 3.4 B	1.6 ± 1.6 B	20 A	1:browning	2.4 ± 0.3 AB
WE02-3	2.4* ± 1.5 B	9.8 ± 5.2 A	30 A	1:2 chlor	2.4 ± 0.2 AB
WE02-4	11.6 ± 2.5 AB	1.2 ± 1.2 B	10 A	1:browning	2.5 ± 0.1 AB

Isolate name	Growth rate 2-4 wks. % ± S.E.	Growth rate 4-6 wks % ± S.E.	% Shoots with disease symptoms	Disease Rating and symptoms	Mean total biomass Per pot ± S.E.
Control	18.2 ± 5.7 A	5.0 ± 2.8 A	0 A	0	2.3 ± 0.1 A
WE02-6	20.6 ± 10 A	3.8 ± 1.7 A	13.3 A	1:browning	2.2 ± 0.2 A
WE02-7	20.4 ± 6.0 A	1.4 ± 0.9 A	10 A	1:browning	1.9 ± 0.4 A
WE02-8	22.2 ± 4.1 A	2.8 ± 1.3 A	10 A	1:brn/wilt	2.5 ± 0.1 A
WE02-9	28.4 ± 16.2 A	5 ± 2.5 A	10 A	1:brn/wilt	2.1 ± 0.3 A
WE02-10		3.2 ± 1.4	0 A	0	2.4 ± 0.1 A
Control	10 ± 3.8 A	3.8 ± 2.6 AB	13.4 A	1: brn	0.4 A
WE02-11	24 ± 4.8 A	2.8 ± 1.3 AB	0 A	0	1.9 ± 0.5 A
WE02-12	16.6 ± 5 A	10.4 ± 4.2 A	30 A	1:slt chlor?	2.3 ± 0.5 A
Pst EB056	27 ± 7.0 A	3.0 ± 1.3 AB	30 A	1-2:chlor.	1.9 ± 0.3 A
Control	15.6 ± 3.7 A	9.6 ± 5.4 A	0 A	0	2.1 ± 0.1 A
WE02-15	17.8 ± 4.4 A	1.0 ± 1.0 A	0 A	0	2.1 ± 0.2 A
WE02-16	24.0 ± 7.5 A	6.2 ± 5.0 A	10 A	1:died	2.3 ± 0.3 A
WE02-17	20.6 ± 2.7 A	3.2 ± 1.4 A	0 A	0	2.0 ± 0.1 A
WE02-18	16.0 ± 6.8 A	0.8 ± 0.8 A	0 A	0	1.8 ± 0.1 A
WE02-19	22.2 ± 2.6 A	1.0 ± 1.0 A	0 A	0	2.2 ± 0.3 A
Control	22.6 ± 6.0 A	4.6 ± 2.6 AB	0 A	0	2.1 ± 0.2 AB
WE02-20	26.4 ± 4.9 A	14.4 ± 5.3 A	0 A	0	2.3 ± 0.2 AB
WE02-21	29.2 ± 7.6 A	2.4 ± 1.0 B	40.0 A	1-2:chlor	2.3 ± 0.2 B
WE02-22	19.8 ± 4.7 A	7.2 ± 3.3 AB	0 A	0	2.3 ± 0.2 AB
FE02-1	22.6 ± 6.0 A	4.6 ± 2.6 AB	0 A	0	2.1 ± 0.2 A
FE02-2	26.4 ± 4.9 A	14.4 ± 5.3 AB	0 A	0	2.3 ± 0.2 AB
Control	18.4 ± 5.6 A	5.4 ± 3.5 A	15.0 A	1:brn	2.0 ± 0.3 A
FE02-3	28.6 ± 6.7 A	0 ± 0 A	33.4 A	1:mildew/chlor	1.3 ± 0.2 A
FE02-4	23.2 ± 3.8 A	7.4 ± 3.1 A	36.6 A	1:2 mildew/chlor	1.2 ± 0.2 A
FE02-5	32.6 ± 9.4 A	2.6 ± 1.2 A	20.0 A	2: chlor	1.7 ± 0.2 A
FE02-6	17.2 ± 5.0 A	4.4 ± 2.9 A	23.4 A	1:2 chlor/brn	1.5 ± 0.3 A
Control	23.0 ± 12.1 A	4.2 ± 3.3 A	0 A	0	1.7 ± 0.3 A
FE02-7	9.0 ± 3.6 A	6.0 ± 1.7 A	16.6 A	1:2 slt chlor	1.9 ± 0.5 A
FE02-8	7.8 ± 2.4 A	4.0 ± 1.9 A	0 A	0	1.9 ± 0.3 A
FE02-9	30 ± 9.0 A	3.4 ± 2.5 A	0 A	0	1.7 ± 0.3 A
FE02-10	39.8 ± 17.9 A	12.0± ± 4.6 A	13.2 A	1:browning	1.9 ± 0.3 A

S.E. = Standard error
*Statistically significant at the 0.05 level of probability.
Ap leaf brn = apical leaf browning
Slt chlor = slight chlorosis
Brn/wilt = browning/wilting

NOTE: It is possible that plants displaying disease symptoms other than chlorosis (ie. mottling, browning, wilting) may have been caused by other factors such as physiological processes, a nematode or fungus in addition to the bacteria

Table 2: Effect of European bacterial strains on growth rate and biomass of Canada thistle and disease symptoms using a root dip and soil drench screening method.

Isolate name	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	% Shoots with disease symptoms	Disease Rating and symptoms	Mean total biomass per pot (g) ± S.E.
Control	81.7± 25.2 A	3.7 ± 1.9 A	0 B	0	1.5 ± 0.5 A
Pst EB056	75.0 ± 31.7 A	6.5 ± 4.5 A	62.5* A	2-3 chlor	1.7 ± 0.5 A
VA02-1	45 ± 16.7 A	5.8 ± 4.3 A	0 B	0	1.6 ± 0.4 A
VA02-2	88.3 ± 20.6 A	14.3 ± 9.5 A	0 B	0	1.9 ± 0.7 A
VA02-3	69.3 ± 22.3 A	4.8 ± 3.1 A	0 B	0	2.0 ± 0.9 A
VA02-4	56.5 ± 9.3 A	14.8 ± 4.9 A	0 B	0	2.2 ± 0.4 A
Control	43.2 ± 7.3 AB	1.2 ± 1.2 B	0 A	0	2.2 ± 0.4 A
VA02-5	130.8 ± 58.2 A	12.2 ± 4.7 AB	0 A	0	2.1 ± 0.3 A
VA02-9	44.6 ± 6.0 AB	6.8 ± 2.2 B	0 A	0	1.6 ± 0.3 A
VA02-10	32.2 ± 15.4 B	6.8 ± 3.2 B	0 A	0	1.7 ± 0.5 A
VA02-11	62.8 ± 27.8 AB	14.6 ± 1.3 AB	0 A	0	2.2 ± 0.7 A
VA02-13	79.4 ± 6.0 AB	21.2 ± 7.2 A	0 A	0	2.1 ± 0.6 A
Control	115.4 ± 21.6 A	14.2 ± 4.4 A	0 A	0	4.2 ± 0.4 A
VA02-14	203.6 ± 53.8 A	8.8 ± 3.2 A	0 A	0	4.9 ± 0.6 A
VA02-15	149.2 ± 42.2 A	29.4 ± 14.5 A	0 A	0	4.3 ± 0.7 A
VA02-16	139 ± 14.9 A	6.2 ± 2.2 A	0 A	0	4.8 ± 0.2 A
VA02-17	183.6 ± 57.2 A	14.8 ± 6.4 A	0 A	0	4.5 ± 0.6 A
Control	80.4 ± 6.9 A	28.2 ± 8.9 A	0 A	0	3.5 ± 0.4 BC
VA02-18	143.4 ± 29.7 A	36.4 ± 8.2 A	0 A	0	2.7 ± 0.2 C
VA02-19	137.8 ± 53.2 A	31.0 ± 9.9 A	0 A	0	4.2 ± 0.4 AB
VA02-20	58.2 ± 19.6 A	23.8 ± 9.8 A	0 A	0	2.8 ± 0.4 C
VA02-21	64.8 ± 11.3 A	19.6 ± 9.8 A	0 A	0	4.8 ± 0.4 A
Control	108.8 ± 13.6 A	17.8 ± 8.3 A	0 B	0	1.1 ± 0.2 A
VA02-22	65.4* ± 10.8 B	29.1 ± 7.0 A	0 B	0	1.4 ± 0.2 A
Pst EB056	50.9* ± 12.8 B	12.8 ± 5.7 A	50* A	2-3: chlorosis	0.8 ± 0.3 A
Control	67.8 ± 7.6 B	24.4 ± 6.2 A	0 A	0	4.4 ± 0.3 A
WE02-1	96 ± 32.7 AB	13.4 ± 5.3 A	0 A	0	5.2 ± 0.5 A
WE02-2	74.8 ± 13.8 B	23.4 ± 8.0 A	0 A	0	4.7 ± 0.7 A
WE02-3	86.8 ± 12.7 AB	16.2 ± 5.0 A	0 A	0	6.0 ± 0.7 A
WE02-4	101.4 ± 8.6 AB	10.2 ± 3.2 A	0 A	0	5.9 ± 0.6 A
WE02-5	153.2 ± 40.9 A	15.2 ± 6.1 A	0.2 A	1: browning	4.8 ± 0.7 A

Isolate name	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	% Shoots with disease symptoms	Disease Rating and symptoms	Mean total biomass per pot (g)±S.E
Control	129.6 ± 56.6 A	27.4 ± 10.9 A	0 A	0	4.4 ± 0.6 A
WE02-6	177.8 ± 60.7 A	20.4 ± 8.5 A	5 A	1: browning	4.0 ± 0.7 A
WE02-7	138.4 ± 14.9 A	9.2 ± 4.3 A	0 A	0	4.4 ± 0.2 A
WE02-8	123.6± 21.4 A	34.6 ± 17.3 A	0 A	0	3.6 ± 0.9 A
WE02-9	121.6 ± 15.4 A	11.6 ± 3.7 A	0 A	0	3.7 ± 0.2 A
WE02-10	129.6 ± 56.6 A	27.4 ± 10.9 A	0 A	0	4.4 ± 0.6 A
Control	135.4 ± 24.9 A	22 ± 5.7 A	0 B	0	2.6 ± 0.6 A
WE02-11	135.4 ± 22.8 A	34.2 ± 11.5 A	0 B	0	3.2 ± 0.4 A
WE02-12	166.2 ± 59.5 A	31.4 ± 17.4 A	0 B	0	2.6 ± 0.5 A
WE02-13	114.6 ± 16.7 A	22.8 ± 6.2 A	0 B	0	2.5 ± 0.5 A
WE02-14	261 ± 160.4 A	37.6 ± 13.2 A	0 B	0	2.2 ± 0.3 A
Pst EB056	138 ± 19.3 A	15.0 ± 6.7 A	30* A	2-3: chlorosis	2.1 ± 0.7A
Control	119.4 ± 29.1 A	33.0 ± 14.9 A	0 A	0	2.0 ± 0.4 A
WE02-15	124.2 ± 24.1 A	24.0 ± 14.1 A	0 A	0	2.0 ± 0.4 A
WE02-16	142 ± 27.8 A	14.8 ± 4.3 A	6.6 A	1: browning	1.9 ± 0.3 A
WE02-17	90.2 ± 16.4 A	15.2 ± 1.2 A	0 A	0	2.5 ± 0.6 A
WE02-18	130 ± 35.7 A	29.4 ± 9.3 A	0 A	0	1.7 ± 0.2 A
WE02-19	103.6 ± 37.0 A	13.6 ± 5.2 A	0 A	0	2.4 ± 0.5 A
Control	150.6 ± 52.4 A	15.6 ± 6.9 A	0 A	0	1.2 ± 0.3 A
WE02-20	131.4 ± 20.4 A	7.8 ± 3.9 A	0 A	0	1.4 ± 0.2 A
WE02-21	136 ± 31.1 A	12.8 ± 3.2 A	0 A	0	2.1 ± 0.4 A
WE02-22	143.4 ± 34.0 A	22.6 ± 8.0 A	0 A	0	1.9 ± 0.5 A
FE02-1	127.3 ± 51.2 A	11.8 ± 3.3 A	0 A	0	1.5 ± 0.4 A
FE02-2	159.0 ± 56.3 A	15.4 ± 8.2 A	0 A	0	1.7 ± 0.3 A
Control	177.6 ± 37.4 A	21.2 ± 9.8 A	0 A	0	1.8 ± 0.2 B
FE02-3	109.4 ± 12.2 A	17.0 ± 7.8 A	0 A	0	2.4 ± 0.2 AB
FE02-4	163 ± 30.2 A	1.8 ± 1.2 A	0 A	0	3.4 ± 0.7 A
FE02-5	99.4 ± 37.7 A	16.2 ± 7.3 A	0 A	0	2.9 ± 0.6 AB
FE02-6	96.8 ± 23.7 A	8.6 ± 2.4 A	0 A	0	1.9 ± 0.4 B
Control	145.6 ± 52.8 A	60.0 ± 9.0 A	0 A	0	2.6 ± 0.5 A
FE02-7	84.2 ± 9.5 A	28.2* ± 7.1 B	0 A	0	2.6 ± 0.4 A
FE02-8	73.8 ± 18.7 A	35.2* ± 3.0 B	6.6 A	1: browning	2.3 ± 0.3 A
FE02-9	142.0 ± 18.9 A	25* ± 10.4 B	0 A	0	3.0 ± 0.2 A
FE02-10	77.2 ± 14.0 A	37.8* ± 6.3 B	0 A	0	2.9 ± 0.6 A

S.E. = Standard error
* Statistically significant at the P=0.05 level of probability

Table 3. Effect of Indigenous and European bacterial strains on shoot growth rate and biomass of Canada thistle plants using a meristem wounding inoculation method.

ISOLATE	Exp #	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	Mean total biomass per pot ± S.E.
Control	1	14.2 ± 4.9	46.2 ± 18.4	5.0 ± 1.1
PST EB056		34.8 ± 16.5	61.5 ± 22.1	5.8 ± 0.8
96-5-Su6-1-C5#2		33.3 ± 13.6	51.8 ± 21.8	6.3 ± 1.1
96-5-Su6-1-C6I2		24.2 ± 9.2	24.6 ± 12.6	4.0 ± 0.6
Control	2	70.6 ± 26.3 A	30.6 ± 10.3 A	6.4 ± 1.5 A
PST EB056		38.6 ± 14.8 A	33.6 ± 14.2 A	3.7 ± 0.7 B
98-75CT3		34.8 ± 9.3 A	13.0 ± 10.2 A	3.4 ± 0.7 B
98-75CT4		39.8 ± 20.7 A	8.4 ± 4.0 A	2.5 ± 0.7 B
98-75CT7		36.2 ± 16.2 A	11.8 ± 6.5 A	4.0 ± 0.5 B
CTB12		42.6 ± 10.8 A	35.4 ± 16.7 A	3.6 ± 0.7 B
Control	3	24.0 ± 8.0 BAC	13.8 ± 8.4 A	3.2 ± 0.7 A
PST EB056		45.8 ± 8.8 BA	29.4 ± 14.1 A	3.8 ± 1.0 A
WRE-03-1		47.4 ± 9.7 A	19.4 ± 16.9 A	3.6 ± 0.7 A
WRE-03-6		23.0 ± 8.4 BC	12.4 ± 6.6 A	2.8 ± 0.6 A
WRE-03-9		20.8 ± 5.8 C	4.8 ± 2.5 A	2.0 ± 0.7 A
WRE-03-10		28.0 ± 7.3 BAC	14.2 ± 7.3 A	3.4 ± 0.5 A
Control	4	15.8 ± 4.4 A	2.8 ± 2.3 B	1.2 ± 0.4
PST EB056		25.4 ± 6.5 A	5.8 ± 3.1 BA	2.4 ± 0.2
UH1-03-2		34.0 ± 11.0 A	4.0 ± 1.5 BA	2.1 ± 0.3
UH1-03-6		41.8 ± 15.2 A	17.2 ± 10.2 A	2.7 ± 0.7 *
UH2-03-3		30.8 ± 5.1 A	4.2 ± 1.3 BA	2.7 ± 0.6 *
UH2-03-5		31.0 ± 8.1 A	7.8 ± 2.4 BA	2.8 ± 0.1 *
Control	5	27.2 ± 3.8 A	8.6 ± 2.4 A	1.5 ± 0.2 A
PST EB056		28.4 ± 6.1 A	2.8 ± 1.3 B	1.3 ± 0.2 A
BIELF1-03-6		38.0 ± 10.2 A	6.2 ± 3.0 BA	1.4 ± 0.3 A
BIELF1-03-8		20.2 ± 4.0 A	1.8 ± 0.7 B	1.0 ± 0.2 A
BIELF1-03-10		29.2 ± 6.3 A	3.2 ± 1.4 BA	0.9 ± 0.3 A
BIELF1-03-12		36.4 ± 12.5 A	3.2 ± 1.8 BA	1.5 ± 0.3 A
Control	6	23.8 ± 3.5 BA	5.0 ± 1.8 B	2.2 ± 0.1
PST EB056		27.4 ± 6.6 A	30.6 ± 14.9 A	2.7 ± 0.3
SIO2-03-3		19.8 ± 3.7 BA	19.8 ± 4.1 BA	2.5 ± 0.4
SIO1-03-9		21.0 ± 3.3 BA	14.2 ± 2.8 BA	2.0 ± 0.3
SIO1-03-4		13.6 ± 4.3 B	11.0 ± 2.7 BA	1.2 ± 0.3 *
SIO1-03-6		18.0 ± 4.1 BA	7.8 ± 2.9 B	2.0 ± 0.3
Control	7	9.0 ± 3.6 B	8.6 ± 3.9 BC	1.7 ± 0.2 C
PST EB056		21.4 ± 4.3 BA	15.4 ± 3.0 BA	1.9 ± 0.4 BC
SIE1-03-4		24.8 ± 5.5 A	14.6 ± 2.2 BA	2.2 ± 0.3 BAC
SIE1-03-7		15.6 ± 3.2 BA	18.8 ± 5.1 A	2.9 ± 0.2 A
FR-03-4		11.2 ± 4.2 BA	10.8 ± 3.9 BAC	2.6 ± 0.1 A
FR-03-2		21.0 ± 8.1 BA	3.2 ± 2.2 C	2.5 ± 0.2 BA
Control	8	23.0 ± 6.9 A	3.6 ± 2.1 B	1.7 ± 0.3 C
PST EB056		28.0 ± 7.1 A	10.4 ± 1.9 BA	1.9 ± 0.4 BC
KIR-03-1		27.6 ± 4.0 A	16.2 ± 4.5 A	2.6 ± 0.3 A
ESP-03-3		17.8 ± 5.7 A	10.0 ± 3.0 BA	2.8 ± 0.2 A
ESP-03-4		32.4 ± 8.7 A	11.6 ± 3.8 BA	2.4 ± 0.3 BA
ESP-03-7		26.8 ± 17.5 A	6.4 ± 2.1 B	2.3 ± 0.3 BAC

ISOLATE	Exp #	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	Mean total biomass per pot ± S.E.
Control	9	52.0 ± 9.6 BAC	16.4 ± 9.0 A	2.2 ± 0.4 A
PST EB056		70.4 ± 11.8 BA	3.8 ± 1.4 A	2.5 ± 0.3 A
DOB1-03-1		35.6 ± 7.6 C	10.8 ± 3.8 A	2.2 ± 0.2 A
DOB1-03-4		47.4 ± 7.3 BC	10.4 ± 8.9 A	2.0 ± 0.4 A
DOB2-03-1		75.4 ± 12.1 A	14.8 ± 5.3 A	2.2 ± 0.2 A
DOB2-03-5		34.0 ± 7.7 C	7.2 ± 3.7 A	2.1 ± 0.5 A
Control	10	32.6 ± 5.1 BCD	7.2 ± 2.2 A	1.7 ± 0.2 A
PST EB056		70.8 ± 12.6 A	2.2 ± 1.0 A	2.2 ± 0.2 A
URC2-03-2		52.0 ± 10.0 BA	15.0 ± 10.7 A	2.0 ± 0.5 A
URC2-03-3		45.6 ± 4.1 BC	1.0 ± 0.6 A	1.9 ± 0.2 A
URC2-03-6		23.6 ± 2.7 CD	8.4 ± 7.4 A	2.2 ± 0.3 A
URC2-03-7		18.0 ± 5.0 D	8.6 ± 8.4 A	2.0 ± 0.3 A
Control	11	22.8 ± 8.8 A	4.8 ± 2.9 A	2.0 ± 0.1 BA
PST EB056		25.4 ± 9.7 A	8.6 ± 1.9 A	2.1 ± 0.3 A
URC3-03-3		18.6 ± 13.0 A	10.2 ± 4.8 A	1.3 ± 0.3 B
URC3-03-5		12.6 ± 4.9 A	4.0 ± 2.0 A	1.8 ± 0.2 BA
URC4-03-1		12.4 ± 3.7 A	5.0 ± 2.0 A	1.5 ± 0.3 BA
URC4-03-3		28.6 ± 11.7 A	3.8 ± 1.1 A	1.9 ± 0.2 BA
Control	12	39.4 ± 14.7 A	13.8 ± 5.9 A	2.3 ± 0.3 A
PST EB056		20.2 ± 4.4 A	4.4 ± 1.3 A	2.0 ± 0.3 A
UGR-03-6		15.8 ± 4.8 A	5.8 ± 3.2 A	2.1 ± 0.5 A
UNP-03-1		17.8 ± 2.8 A	6.2 ± 1.2 A	1.7 ± 0.4 A
UNP-03-3		37.0 ± 13.0 A	14.6 ± 7.1 A	2.8 ± 0.4 A
UNP-03-5		17.8 ± 5.4 A	5.0 ± 1.7 A	1.8 ± 0.3 A
Control	13	15.6 ± 7.1 B	5.2 ± 2.3 A	2.3 ± 0.5 A
PST EB056		31.4 ± 5.6 AB	9.4 ± 5.3 A	2.0 ± 0.4 A
WRE-03-12		44.2 ± 8.3 A	8.8 ± 2.8 A	2.2 ± 0.2 A
WRE-03-14		32.0 ± 8.7 AB	4.0 ± 0.6 A	2.2 ± 0.3 A
WRE-03-18		33.0 ± 10.1 AB	5.0 ± 1.3 A	2.1 ± 0.3 A
WRE-03-19		24.2 ± 2.5 AB	4.8 ± 3.0 A	2.1 ± 0.4 A
Control	14	21.2 ± 6.9 A	5.2 ± 0.9 B	2.3 ± 0.2 A
PST EB056		43.4 ± 13.7 A	7.4 ± 3.0 BA	2.4 ± 0.3 A
UH2-03-6		46.0 ± 17.6 A	8.6 ± 5.1 BA	3.2 ± 0.3 A
UH2-03-10		23.4 ± 6.2 A	7.2 ± 4.1 BA	2.4 ± 0.2 A
UH2-03-13		38.6 ± 7.7 A	10.2 ± 2.3 BA	2.5 ± 0.5 A
UH2-03-14		44.0 ± 1.5 A	16.2 ± 3.4 A	2.4 ± 0.1 A
UH2-03-15		24.4 ± 10.1 A	10.6 ± 3.2 BA	3.5 ± 1.2 A
BIELF3-03-1		18.2 ± 3.7 A	11.6 ± 2.3 BA	3.1 ± 0.5 A
Control	15	44.4 ± 12.7 BA	16.0 ± 5.3 A	3.1 ± 0.3 B
PST EB056		45.2 ± 18.3 A	1.8 ± 1.2 B	3.3 ± 0.3 BA
BIELF3-03-6		28.6 ± 13.8 BAC	7.6 ± 3.3 B	3.0 ± 0.2 B
BIELF3-03-8		38.4 ± 10.3 BAC	3.2 ± 2.1 B	4.0 ± 0.1 A
BIELF3-03-10		25.4 ± 8.6 BAC	4.4 ± 1.9 B	3.5 ± 0.4 BA
BIELF3-03-15		9.4 ± 3.5 C	3.2 ± 2.1 B	3.4 ± 0.1 BA
BIELF1-03-1		30.2 ± 14.7 BAC	5.8 ± 2.7 B	3.2 ± 0.4 BA
BIELF2-03-5		11.0 ± 6.0 BC	4.6 ± 3.2 B	3.2 ± 0.3 BA

ISOLATE	Exp #	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	Mean total biomass per pot ± S.E.
Control	16	22.0 ± 13.3 B	6.0 ± 0.9 AB	3.4 ± 0.7 A
PST EB056		56.8 ± 16.6 A	10.4 ± 4.7 A	2.3 ± 0.5 A
BIELF2-03-7		16.8 ± 8.4 B	7.2 ± 1.7 AB	2.7 ± 0.3 A
BIELF2-03-1		22.2 ± 10.4 B	2.8 ± 1.8 AB	3.0 ± 0.5 A
SIO2-03-1		18.0 ± 8.7 B	9.4 ± 4.5 A	3.4 ± 0.2 A
SIE2-03-4		19.2 ± 8.4 B	6.8 ± 3.7 AB	3.4 ± 0.4 A
SIE2-03-1		17.8 ± 8.5 B	1.0 ± 0.4 B	2.4 ± 0.4 A
SIE1-03-5		10.8 ± 2.9 B	9.0 ± 3.3 A	2.9 ± 0.4 A
Control	17	41.4 ± 10.6 A	3.2 ± 1.2 AB	3.4 ± 0.6 A
PST EB056		11.6 ± 8.1 B	6.6 ± 1.9 A	4.3 ± 0.3 A
GOT-03-3		17.0 ± 6.4 AB	4.6 ± 1.0 AB	4.7 ± 0.2 A
GOT-03-6		11.2 ± 5.3 B	3.4 ± 2.1 AB	4.2 ± 0.6 A
GOT-03-9		23.2 ± 3.4 AB	1.8 ± 1.2 B	4.7 ± 0.4 A
GOT-03-12		22.6 ± 13.4 AB	2.0 ± 0.9 B	4.3 ± 0.3 A

S.E. = Standard error
Isolates with the same letter are not significant at the 0.05 level of probability
Isolates with * are statisticaly significant at the 0.05 level of probability

Table 4. Effect of Indigenous and European bacterial strains on shoot growth rate and biomass of Canada thistle plants using a root dip and soil drench screening method.

ISOLATE	Exp #	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	Mean total biomass per pot ± S.E.
Control	1	98.2 ± 11.4 A	56.4 ± 9.8 A	4.2 ± 0.7 A
PST EB056		284.0 ± 209.7 A	43.8 ± 10.9 A	2.7 ± 0.7 AB
96-5-Su6-1-C5#2		105.6 ± 20.6 A	48.8 ± 9.2 A	3.6 ± 0.3 A
96-5-Su6-1-C6I2		56.2 ± 8.3 A	30.2 ± 8.0 A	2.0 ± 0.4 B
Control	2	151.3 ± 36.8	40.3 ± 17.6	1.5 ± 0.6
PST EB056		76.6 ± 38.1	59.6 ± 7.2	1.6 ± 0.5
98-75CT3		81.0 ± 22.4	32.8 ± 5.9	1.4 ± 0.2
98-75CT4		70.0 ± 18.0	35.0 ± 1.0	1.2 ± 0.0
98-75CT7		69.2 ± 10.8	31.6 ± 6.1	1.7 ± 0.1
CTB12		88.4 ± 13.6	51.2 ± 6.4	1.9 ± 0.2
Control	3	99.8 ± 21.3	54.2 ± 17.7	2.8 ± 0.7
PST EB056		115.3 ± 12.7	68.0 ± 24.3	4.0 ± 1.5
WRE-03-1		45.8 ± 11.9	34.0 ± 8.5	2.9 ± 0.2
WRE-03-6		113.0 ± 11.2	61.6 ± 10.1	2.6 ± 0.7
WRE-03-9		110.4 ± 28.1	69.8 ± 13.0	4.4 ± 1.6
WRE-03-10		111.0 ± 20.6	73.6 ± 17.9	4.1 ± 1.0
Control	4	74.8 ± 8.8 A	49.0 ± 9.2 A	2.7 ± 0.4
PST EB056		127.2 ± 13.8 A	57.6 ± 9.3 A	2.1 ± 0.3
UH1-03-2		123.6 ± 13.7 A	64.0 ± 9.0 A	2.4 ± 0.3
UH1-03-6		108.0 ± 23.0 A	67.2 ± 10.6 A	4.3 ± 1.3
UH2-03-3		86.4 ± 29.1 A	63.8 ± 20.2 A	1.4 ± 0.3
UH2-03-5		123.8 ± 28.1 A	46.6 ± 10.4 A	1.0 ± 0.2

ISOLATE	Exp #	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	Mean total biomass per pot ± S.E.
Control	5	123.5 ± 12.3 B	10.5 ± 4.5	1.8 ± 0.4 B
PST EB056		52.0 ± 22.1 A *	23.6 ± 6.1	0.5 ± 0.2 A*
BIELF1-03-6		53.4 ± 8.0 A*	17.2 ± 3.8	1.9 ± 0.3 B
BIELF1-03-8		55.4 ± 16.5 A*	31.4 ± 8.1	1.5 ± 0.2 B
BIELF1-03-10		60.2 ± 15.5 A*	52.2 ± 11.0 *	1.5 ± 0.4 B
BIELF1-03-12		90.4 ± 22.7 B	36.2 ± 10.4	2.8 ± 0.3 C*
Control	6	153.4 ± 29.5 BC	21.6 ± 6.2 A	1.4 ± 0.3 A
PST EB056		251.2 ± 96.0 BA	31.0 ± 18.4 A	0.6 ± 0.2 B
SIO2-03-3		121.4 ± 38.0 BC	26.2 ± 9.3 A	1.3 ± 0.2 A
SIO1-03-9		134.2 ± 20.2 BC	20.4 ± 9.1 A	1.5 ± 0.2 A
SIO1-03-4		75.8 ± 7.0 C	31.2 ± 8.7 A	1.8 ± 0.3 A
SIO1-03-6		375.2 ± 86.6 A	28.8 ± 7.0 A	1.2 ± 0.2 BA
Control	7	98.6 ± 9.2 A	19.4 ± 4.7 C	2.3 ± 0.1 DC
PST EB056		136.8 ± 67.7 A	37.0 ± 4.0 BAC	1.6 ± 0.3 D
SIE1-03-4		95.6 ± 7.7 A	66.2 ± 26.0 A	2.5 ± 0.4 BDC
SIE1-03-7		101.2 ± 27.9 A	64.4 ± 18.5 BA	3.6 ± 0.4 A
FR-03-4		151.0 ± 63.0 A	34.6 ± 6.3 BAC	2.6 ± 0.4 BAC
FR-03-2		124.8 ± 13.6 A	23.6 ± 8.2 BC	3.3 ± 0.6 BA
Control	8	442.4 ± 161.2	34.0 ± 15.7 B	2.8 ± 0.4 BA
PST EB056		358.6 ± 77.5	44.2 ± 9.9 BA	2.3 ± 0.3 B
KIR-03-1		292.4 ± 56.9	38.2 ± 5.0 B	3.3 ± 0.3 A
ESP-03-3		128.5 ± 23.8	75.4 ± 15.3 A	2.4 ± 0.3 BA
ESP-03-4		322.6 ± 116.9	47.2 ± 7.6 BA	2.8 ± 0.4 BA
ESP-03-7		383.0 ± 189.4	25.2 ± 9.2 B	2.5 ± 0.2 BA
Control	9	208.8 ± 34.6 A	25.8 ± 8.2 BA	2.3 ± 0.3 A
PST EB056		196.6 ± 39.4 A	29.2 ± 4.2 BA	1.7 ± 0.3 BA
DOB1-03-1		172.0 ± 40.8 A	18.4 ± 3.2 B	1.3 ± 0.2 B
DOB1-03-4		141.0 ± 52.6 A	40.8 ± 11.5 A	2.3 ± 0.3 A
DOB2-03-5		193.2 ± 34.5 A	31.6 ± 11.1 BA	1.4 ± 0.2 B
Control	10	367.4 ± 184.0 A	27.6 ± 8.0 A	1.3 ± 0.1 BA
PST EB056		400.8 ± 156.1 A	17.4 ± 8.6 BA	0.9 ± 0.1 B
URC2-03-2		179.6 ± 39.7 A	1.4 ± 1.4 B	1.3 ± 0.3 BA
URC2-03-6		470.4 ± 325.4 A	22.4 ± 5.4 A	1.5 ± 0.2 A
URC2-03-7				
Control	11	58.8 ±21.9 B	11.2 ± 5.0 BC	1.8 ± 0.3 A
PST EB056		29.6 ± 11.2 B	6.0 ± 2.2 C	1.5 ± 0.4 A
URC3-03-3		71.6 ± 11.3 AB	33.0 ± 8.2 BAC	1.6 ± 0.4 A
URC3-03-5		52.8 ± 9.7 B	39.8 ± 11.9 BA	2.5 ± 0.5 A
URC4-03-1		36.0 ± 19.5 B	54.0 ± 20.7 A	1.8 ± 0.3 A
URC4-03-3		107.0 ± 14.2 A	39.2 ± 3.9 BA	2.2 ± 0.7 A
Control	12	67.8 ± 13.4 A	9.0 ± 3.5 A	2.1 ± 0.3 A
PST EB056		80.0 ± 14.5 A	14.0 ± 7.6 A	1.7 ± 0.2 A
UGR-03-6		105.2 ± 45.5 A	21.4 ± 9.1 A	2.3 ± 0.5 A
UNP-03-1		94.8 ± 20.6 A	20.8 ± 4.6 A	2.2 ± 0.2 A
UNP-03-3		85.8 ± 18.4 A	11.4 ± 3.6 A	2.6 ± 0.5 A
UNP-03-5		149.0 ± 74.7 A	7.4 ± 3.9 A	1.5 ± 0.2 A

ISOLATE	Exp #	Growth rate 2-4 wks. (%) ± S.E.	Growth rate 4-6 wks. (%) ± S.E.	Mean total biomass per pot ± S.E.
Control	13	137.6 ± 32.0	21.2 ± 5.8 C	4.1 ± 0.4 A
DOB2-03-1		76.2 ± 19.1	6.4 ± 3.4 C	2.6 ± 0.4 B
URC2-03-3		102.8 ± 22.8	9.8 ± 2.6 C	2.2 ± 0.3 CB
PST EB056		113.6 ± 17.9	5.6 ± 2.6 C	1.8 ± 0.3 CB
WRE-03-12		262.6 ± 101.6	67.6 ± 9.5 A	2.0 ± 0.4 CB
WRE-03-14		82.6 ± 34.3	50.2 ± 10.3 BA	1.8 ± 0.4 CB
WRE-03-18		143.0 ± 27.7	14.8 ± 7.0 C	2.0 ± 0.3 CB
WRE-03-19		199.3 ± 37.8	31.0 ± 20.2 BC	1.5 ± 0.4 C
Control	14	221.8 ± 34.3 A	40.0 ± 15.9 AB	6.7 ± 0.3 AB
PST EB056		222.0 ± 29.0 A	50.4 ± 9.9 A	7.1 ± 0.6 A
UH2-03-6		203.0 ± 21.7 BA	30.6 ± 3.5 BA	5.7 ± 0.6 B
UH2-03-10		158.2 ± 13.6 BAC	23.2 ± 4.4 BA	5.7 ± 0.3 B
UH2-03-13		90.0 ± 28.8 C	14.8 ± 5.0 B	6.0 ± 0.4 AB
UH2-03-14		124.4 ± 28.3 BC	27.8 ± 14.5 BA	6.1 ± 0.6 AB
UH2-03-15		128.8 ± 25.5 BC	32.4 ± 12.7 BA	6.2 ± 0.7 AB
BIELF3-03-1		198.0 ± 35.1 BA	35.2 ± 7.7 BA	6.6 ± 0.4 AB
Control	15	119.4 ± 22.9 A	39.0 ± 12.7 A	5.6 ± 0.3 BA
PST EB056		70.0 ± 14.4 A	28.2 ± 7.9 A	4.7 ± 0.4 B
BIELF3-03-6		62.2 ± 12.5 A	33.0 ± 8.9 A	5.0 ± 0.9 BA
BIELF3-03-8		98.2 ± 37.5 A	43.2 ± 15.3 A	5.2 ± 0.6 BA
BIELF3-03-10		120.2 ± 11.7 A	29.6 ± 4.7 A	5.8 ± 0.2 BA
BIELF3-03-15		186.4 ± 75.9 A	37.2 ± 9.0 A	5.4 ± 0.2 BA
BIELF1-03-1		167.4 ± 119.2 A	39.4 ± 12.4 A	5.1 ± 0.5 BA
BIELF2-03-5		90.0 ± 14.7 A	37.6 ± 3.4 A	6.4 ± 1.1 A
Control	16	330.4 ± 77.8	525.6 ± 18.2 A	3.8 ± 0.5 BC
PST EB056		134.6 ± 19.5	13.2 ± 7.2 B	3.7 ± 0.6 BC
BIELF2-03-7		231.2 ± 120.3	12.6 ± 5.2 B	4.4 ± 0.6 AB
BIELF2-03-1		154.8 ± 14.7	28.6 ± 5.8 AB	3.5 ± 0.7 BC
SIO2-03-1		124.0 ± 23.7	31.6 ± 25.4 AB	3.0 ± 0.7 C
SIE2-03-4		321.6 ± 149.9	21.0 ± 15.3 AB	3.6 ± 0.6 BC
SIE2-03-1		234.4 ± 129.8	30.8 ± 11.8 AB	5.3 ± 0.7 A
SIE1-03-5		168.8 ± 91.1	20.4 ± 9.7 AB	4.6 ± 0.2 AB
Control	17	164.0 ± 50.1 A	24.8 ± 8.7 AB	2.6 ± 0.3 B
PST EB056		130.6 ± 25.6 AB	10.8 ± 3.4 B	2.9 ± 0.7 AB
GOT-03-3		67.8 ± 18.2 B	18.4 ± 8.1 B	3.6 ± 0.5 AB
GOT-03-6		63.6 ± 12.6 B	6.4 ± 3.4 B	2.7 ± 0.4 B
GOT-03-9		98.2 ± 16.2 AB	20.4 ± 5.5 B	3.9 ± 0.3 A
GOT-03-12		111.2 ± 28.6 AB	42.0 ± 10.9 A	3.2 ± 0.5 AB

S.E. = Standard error
Isolates with the same letter are not significant at the 0.05 level of probability
Isolates with the same letter are not significant at the 0.05 level of probability

Table 5. Effect of indigenous and European bacterial strains on disease symptoms of Canada thistle plants using meristem wounding inoculation method.

ISOLATE	% Shoots with disease symptoms at 2 wks	Disease Rating and symptoms at 2 wks	% Shoots with disease symptoms at 4 wks	Disease Rating and symptoms at 4 wks	% Shoots with disease symptoms at 6 wks	Disease Rating and symptoms at 6 wks
Control	0	0	0	0	0	0
PST EB056	25	1	25	2	25	3
96-5-Su6-1-C5#2	0	0	0	0	0	0
96-5-Su6-1-C6I2	0	0	0	0	0	0
Control	0 B	0	0 A	0	0 A	0
PST EB056	80 A	1-2	0 A	0	0 A	0
98-75CT3	0 B	0	0 A	0	20 A	dead
98-75CT4	60 A	1-2	0 A	0	0 A	0
98-75CT7	40 BA	1-2	0 A	0	0 A	0
CTB12	60 A	1-2	0 A	0	0 A	0
Control	0 B	0	0 A	0	0 A	0
PST EB056	40 A	1	20 A	1	20 A	2
WRE-03-1	0 B	0	0 A	0	0 A	0
WRE-03-6	0 B	0	0 A	0	0 A	0
WRE-03-9	0 B	0	0 A	0	0 A	0
WRE-03-10	0 B	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	20 A	dead
PST EB056	40 A	1-3	20 A	3	0 A	0
UH1-03-2	0 A	0	0 A	0	0 A	0
UH1-03-6	0 A	0	0 A	0	0 A	0
UH2-03-3	0 A	0	0 A	0	0 A	0
UH2-03-5	40 A	1-slt chlor	20 A	2	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	20 A	1-2	20 A	1-2	20 A	1
BIELF1-03-6	0 A	0	0 A	0	0 A	0
BIELF1-03-8	0 A	0	0 A	0	0 A	0
BIELF1-03-10	0 A	0	0 A	0	20 A	2
BIELF1-03-12	0 A	0	0 A	0	0 A	0
Control	0 B	0	0 B	0	0 A	0
PST EB056	80 A	2-3	40 A	3	0 A	0
SIO2-03-3	0 B	0	0 B	0	0 A	0
SIO1-03-9	0 B	0	0 B	0	0 A	0
SIO1-03-4	0 B	0	0 B	0	0 A	0
SIO1-03-6	0 B	0	0 B	0	0 A	0
Control	0 B	0	0 A	0	0 A	0
PST EB056	40 A	2-3	40 A	dead, 2	0 A	0
SIE1-03-4	0 B	0	20 A	2	0 A	0
SIE1-03-7	0 B	0	20 A	1-2	0 A	0
FR-03-4	0 B	0	0 A	0	0 A	0
FR-03-2	0 B	0	0 A	0	0 A	0

ISOLATE	% Shoots with disease symptoms at 2 wks	Disease Rating and symptoms at 2 wks	% Shoots with disease symptoms at 4 wks	Disease Rating and symptoms at 4 wks	% Shoots with disease symptoms at 6 wks	Disease Rating and symptoms at 6 wks
Control	0 B	0	0 A	0	0 A	0
PST EB056	40 A	2-3 mod chlor	20 A	2-slt chlor	0 A	0
KIR-03-1	0 B	0	0 A	0	20 A	1-slt pale
ESP-03-3	0 B	0	0 A	0	0 A	0
ESP-03-4	0 B	0	0 A	0	0 A	0
ESP-03-7	0 B	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	20 A	2 slt chlor	0 A	0	20 A	1 stunted
DOB1-03-1	0 A	0	0 A	0	0 A	0
DOB1-03-4	0 A	0	0 A	0	0 A	0
DOB2-03-1	0 A	0	0 A	0	0 A	0
DOB2-03-5	0 A	0	0 A	0	0 A	0
Control	0 B	0	0 A	0	0 A	0
PST EB056	80 A	2	0 A	0	20 A	dead
URC2-03-2	0 B	0	0 A	0	0 A	0
URC2-03-3	0 B	0	0 A	0	0 A	0
URC2-03-6	0 B	0	0 A	0	0 A	0
URC2-03-7	20 B	2 slt chlor	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	20 A	2 slt chlor	0 A	0
URC3-03-3	0 A	0	20 A	1	20 A	2 very slt chlr
URC3-03-5	0 A	0	40 A	2 slt chlor	20 A	2
URC4-03-1	0 A	0	40 A	2	0 A	0
URC4-03-3	0 A	0	20 A	2	40 A	2
Control	0 B	0	0 A	0	0 A	0
PST EB056	60 A	1-2	20 A	2	20 A	2
UGR-03-6	20 BA	1	20 A	2 very slt chlor	20 A	2 slt chlor
UNP-03-1	0 B	0	0 A	0	0 A	0
UNP-03-3	20 BA	1	0 A	0	0 A	0
UNP-03-5	20 BA	1	0 A	0	0 A	0
Control	0 B	0	0 B	0	0 A	0
PST EB056	80 A	3 mod chlor	60 A	2 chlor	0 A	0
WRE-03-12	40 BA	1 stunted	0 B	0	0 A	0
WRE-03-14	0 B	0	0 B	0	0 A	0
WRE-03-18	40 BA	2 slt chlor	20 B	2 slt chlor	0 A	0
WRE-03-19	0 B	0	0 B	0	0 A	0
Control	0 B	0	0 B	0	0 A	0
PST EB056	60 A	3	60 A	2	0 A	0
UH2-03-6	0 B	0	0 B	0	0 A	0
UH2-03-10	0 B	0	0 B	0	0 A	0
UH2-03-13	0 B	0	0 B	0	0 A	0
UH2-03-14	20 B	2 slt chlor	0 B	0	0 A	0
UH2-03-15	0 B	0	0 B	0	0 A	0
BIELF3-03-1	0 B	0	0 B	0	0 A	0

ISOLATE	% Shoots with disease symptoms at 2 wks	Disease Rating and symptoms at 2 wks	% Shoots with disease symptoms at 4 wks	Disease Rating and symptoms at 4 wks	% Shoots with disease symptoms at 6 wks	Disease Rating and symptoms at 6 wks
Control	0 B	0	0 A	0	0 A	0
PST EB056	40 A	2 slt chlor	0 A	0	0 A	0
BIELF3-03-6	0 B	0	0 A	0	0 A	0
BIELF3-03-8	0 B	0	0 A	0	0 A	0
BIELF3-03-10	0 B	0	0 A	0	0 A	0
BIELF3-03-15	0 B	0	0 A	0	0 A	0
BIELF1-03-1	0 B	0	0 A	0	0 A	0
BIELF2-03-5	0 B	0	0 A	0	0 A	0
Control	0 B	0	0 B	0	0 A	0
PST EB056	80 A	3	60 A	2	0 A	0
BIELF2-03-7	0 B	0	0 B	0	0 A	0
BIELF2-03-1	0 B	0	0 B	0	0 A	0
SIO2-03-1	0 B	0	0 B	0	0 A	0
SIE2-03-4	0 B	0	0 B	0	0 A	0
SIE2-03-1	0 B	0	0 B	0	0 A	0
SIE1-03-5	0 B	0	0 B	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	20 A	3	20 A	2	0 A	0
GOT-03-3	0 A	0	0 A	0	0 A	0
GOT-03-6	0 A	0	0 A	0	0 A	0
GOT-03-9	0 A	0	0 A	0	0 A	0
GOT-03-12	0 A	0	0 A	0	0 A	0

S.E. = Standard error
mod chlor = moderate chlorosis
slt chlor = slight chlorosis
Isolates with the same letter are not significant at the 0.05 level of probability
Isolates with * are statisticaly significant at the 0.05 level of probability

Table 6. Effect of indigenous and European bacterial strains on disease symptoms of Canada thistle plants using a root dip and soil drench screening method.

ISOLATE	% Shoots with disease symptoms at 2 wks	Disease Rating and symptoms at 2 wks	% Shoots with disease symptoms at 4 wks	Disease Rating and symptoms at 4 wks	% Shoots with disease symptoms at 6 wks	Disease Rating and symptoms at 6 wks
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
96-5-Su6-1-C5#2	0 A	0	0 A	0	0 A	0
96-5-Su6-1-C6I2	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
98-75CT3	0 A	0	0 A	0	0 A	0
98-75CT4	0 A	0	0 A	0	0 A	0
98-75CT7	0 A	0	0 A	0	0 A	0
CTB12	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	25 A	2	0 A	0	0 A	0
WRE-03-1	0 A	0	0 A	0	0 A	0
WRE-03-6	0 A	0	0 A	0	0 A	0
WRE-03-9	0 A	0	0 A	0	0 A	0
WRE-03-10	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
UH1-03-2	0 A	0	0 A	0	0 A	0
UH1-03-6	0 A	0	0 A	0	0 A	0
UH2-03-3	0 A	0	0 A	0	0 A	0
UH2-03-5	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	20 A	2 slt chlor	0 A	0	0 A	0
BIELF1-03-6	0 A	0	0 A	0	0 A	0
BIELF1-03-8	0 A	0	0 A	0	0 A	0
BIELF1-03-10	0 A	0	0 A	0	0 A	0
BIELF1-03-12	0 A	0	0 A	0	0 A	0
Control	0 B	0	0 A	0	0 A	0
PST EB056	40 A	2-3	20 A	2-3	0 A	0
SIO2-03-3	0 B	0	0 A	0	0 A	0
SIO1-03-9	0 B	0	0 A	0	0 A	0
SIO1-03-4	0 B	0	0 A	0	0 A	0
SIO1-03-6	0 B	0	0 A	0	0 A	0
Control	0 B	0	0 A	0	20 A	1
PST EB056	80 A	2-3	20 A	2	0 A	0
SIE1-03-4	0 B	0	0 A	0	20 A	1
SIE1-03-7	0 B	0	0 A	0	0 A	0
FR-03-4	0 B	0	0 A	0	20 A	1
FR-03-2	0 B	0	0 A	0	20 A	1

ISOLATE	% Shoots with disease symptoms at 2 wks	Disease Rating and symptoms at 2 wks	% Shoots with disease symptoms at 4 wks	Disease Rating and symptoms at 4 wks	% Shoots with disease symptoms at 6 wks	Disease Rating and symptoms at 6 wks
Control	0 B	0	0 A	0	20 A	1
PST EB056	60 A *	2-3	20 A	2-3	40 A	1
KIR-03-1	20 B	3	0 A	0	0 A	0
ESP-03-3	0 B	0	0 A	0	0 A	0
ESP-03-4	0 B	0	0 A	0	20 A	1
ESP-03-7	0 B	0	0 A	0	40 A	1-2
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
DOB1-03-1	0 A	0	0 A	0	0 A	0
DOB1-03-4	0 A	0	0 A	0	0 A	0
DOB2-03-5	0 A	0	0 A	0	0 A	0
Control	0 B	0	0 A	0	0 A	0
PST EB056	60 A	2	0 A	0	0 A	0
URC2-03-2	0 B	0	0 A	0	0 A	0
URC2-03-6	0 B	0	0 A	0	0 A	0
URC2-03-7						
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
URC3-03-3	20 A	2 pale green	0 A	0	0 A	0
URC3-03-5	0 A	0	0 A	0	0 A	0
URC4-03-1	0 A	0	0 A	0	0 A	0
URC4-03-3	20 A	2 pale green	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
UGR-03-6	0 A	0	0 A	0	0 A	0
UNP-03-1	0 A	0	0 A	0	0 A	0
UNP-03-3	0 A	0	0 A	0	0 A	0
UNP-03-5	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
DOB2-03-1	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
URC2-03-3	0 A	0	0 A	0	0 A	0
WRE-03-12	0 A	0	0 A	0	0 A	0
WRE-03-14	0 A	0	0 A	0	0 A	0
WRE-03-18	0 A	0	0 A	0	0 A	0
WRE-03-19	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	20 A	2	0 A	0	0 A	0
UH2-03-6	20 A	2	0 A	0	0 A	0
UH2-03-10	0 A	0	0 A	0	0 A	0
UH2-03-13	0 A	0	0 A	0	0 A	0
UH2-03-14	0 A	0	0 A	0	0 A	0
UH2-03-15	0 A	0	0 A	0	0 A	0
BIELF3-03-1	0 A	0	0 A	0	0 A	0

ISOLATE	% Shoots with disease symptoms at 2 wks	Disease Rating and symptoms at 2 wks	% Shoots with disease symptoms at 4 wks	Disease Rating and symptoms at 4 wks	% Shoots with disease symptoms at 6 wks	Disease Rating and symptoms at 6 wks
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
BIELF3-03-6	0 A	0	0 A	0	0 A	0
BIELF3-03-8	0 A	0	0 A	0	0 A	0
BIELF3-03-10	0 A	0	0 A	0	0 A	0
BIELF3-03-15	0 A	0	0 A	0	0 A	0
BIELF1-03-1	0 A	0	0 A	0	0 A	0
BIELF2-03-5	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
BIELF2-03-7	0 A	0	0 A	0	0 A	0
BIELF2-03-1	0 A	0	0 A	0	0 A	0
SIO2-03-1	0 A	0	0 A	0	0 A	0
SIE2-03-4	0 A	0	0 A	0	0 A	0
SIE2-03-1	0 A	0	0 A	0	0 A	0
SIE1-03-5	0 A	0	0 A	0	0 A	0
Control	0 A	0	0 A	0	0 A	0
PST EB056	0 A	0	0 A	0	0 A	0
GOT-03-3	0 A	0	0 A	0	0 A	0
GOT-03-6	0 A	0	0 A	0	0 A	0
GOT-03-9	0 A	0	0 A	0	0 A	0
GOT-03-12	0 A	0	0 A	0	0 A	0

S.E. = Standard error
mod chlor = moderate chlorosis
slt chlor = slight chlorosis
Isolates with the same letter are not significant at the 0.05 level of probability
Isolates with * are statisticaly significant at the 0.05 level of probability

Evaluation of Screening Methods and Asteraceae Indicator Plants

Table 7a. Effect of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, and Canada thistle) using 3 inoculation methods.

	Asteraceae Indicator Plants		
Inoculation Methods	Sunflower	Marigold	Canada Thistle
Untreated Control	69.1 a	24.4 c	4.0 d
Meristem (stab)	61.6 b	20.0 c	2.7 d
Wounding	60.9 b	22.3 c	2.7 d
Airbrush*	7.7 d	3.5 d	2.3 d

*Foliar application using Silwet L77 at 0.3% (v/v)

Table 7b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using 3 inoculation methods.

	Asteraceae Indicator Plants								
Inoculation	Sunflower			Marigold			Canada Thistle		
Methods	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Meristem (stab)	0.25	1	1.5	0.25	1.5	2	0.25	0.25	0.75
Wounding	0.75	1	2	0	1.25	1.5	0.5	0.5	0.25
Airbrush*	4	4.25	4.75	3.75	4.5	4.75	4	4	1.25

*Foliar application using Silwet L77 at 0.3% (v/v)

Table 8a. Effect of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, and Canada thistle) using 3 inoculation methods.

	Asteraceae Indicator Plants		
Inoculation Methods	Sunflower	Marigold	Canada Thistle
Untreated Control	61.3 a	31.9 c	4.7 f
Meristem (stab)	48.5 b	25.9 d	3.8 f
Wounding	58.9 a	24.5 de	4.3 f
Airbrush*	50.3 b	19.5 e	3.1 f

*Foliar application using Silwet L77 at 0.1% (v/v)

Table 8b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using 3 inoculation methods.

	Asteraceae Indicator Plants								
Inoculation	Sunflower			Marigold			Canada Thistle		
Methods	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Meristem (stab)	1.75	2	2.5	1.75	2.25	2.25	0.25	1	0.75
Wounding	1.5	0.75	1	1.25	2	2	0.75	1	0.75
Airbrush*	2.75	2	2	2.5	2.75	3.25	0.75	0.75	1

*Foliar application using Silwet L77 at 0.1% (v/v)

Table 9a. Effect of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, and Canada thistle) using 3 inoculation methods.

	Asteraceae Indicator Plants		
Inoculation Methods	Sunflower	Marigold	Canada Thistle
Untreated Control	70.3 a	18.2 c	5.5 e
Meristem (stab)	55.2 b	18.6 c	5.0 e
Wounding	68.6 a	18.2 c	6.2 de
Airbrush*	54.6 b	16.6 cd	6.8 de

*Foliar application using Silwet L77 at 0.1% (v/v)

Table 9b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using 3 inoculation methods.

	Asteraceae Indicator Plants								
Inoculation	Sunflower			Marigold			Canada Thistle		
Methods	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Meristem (stab)	1.5	1.5	2	0	1.5	1.5	0	0.25	1
Wounding	1.5	1.25	2	0.5	1.5	2	0.5	0.25	0.25
Airbrush*	2	2	2.5	2	3.5	3.5	1	0.75	0.25

*Foliar application using Silwet L77 at 0.1% (v/v)

Table 10a. Effect of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, and Canada thistle) using 3 inoculation methods.

	Asteraceae Indicator Plants		
Inoculation Methods	Sunflower	Marigold	Canada Thistle
Untreated Control	71.7 a	21.1 c	7.9 cd
Meristem (stab)	39.5 b	13.6 cd	6.2 cd
Wounding	64.1 a	18.2 cd	5.9 d
Airbrush*	36.8 b	10.3 cd	6.7 cd

*Foliar application using Silwet L77 at 0.15% (v/v)

Table 10b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using 3 inoculation methods.

	Asteraceae Indicator Plants								
Inoculation	Sunflower			Marigold			Canada Thistle		
Methods	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Meristem (stab)	1.75	2	2	1.75	2.25	2.5	0.5	1	1
Wounding	1.75	1.75	1	1.25	1.5	1.5	1	1	1
Airbrush*	2	3	2.75	2.75	3.25	3.25	1.75	1.5	1

*Foliar application using Silwet L77 at 0.15% (v/v)

Table 11a. Effect of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, and Canada thistle) using 3 inoculation methods. (Expt 1)

	Asteraceae Indicator Plants		
Inoculation Methods	Sunflower	Marigold	Canada Thistle
Untreated Control	70.9 a	23.0 b	7.1 c
Silwet w/o PST	75.3 a	20.5 b	8.4 c
Fresh PST*	21.8 b	4.0 c	6.0 c
Freezer PST*	27.8 b	6.1 c	5.3 c

*Foliar application using airbrush and Silwet L77 at 0.2% (v/v) as formulation

Table 11b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using 3 inoculation methods. (Expt 1)

	Asteraceae Indicator Plants								
Inoculation	Sunflower			Marigold			Canada Thistle		
Methods	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Silwet w/o PST	1	0.75	0	1	0	0.5	1	0.75	0.25
Fresh PST*	3	3.5	3.5	3	3.75	4.25	2	2.5	2.25
Freezer PST*	3	3.25	3.25	2.5	3.25	4.25	2.5	2.75	2.25

*Foliar application using airbrush and Silwet L77 at 0.2% (v/v) as formulation

Table 12a. Effect of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, and Canada thistle) using 3 inoculation methods. (Expt 2)

	Asteraceae Indicator Plants		
Inoculation Methods	Sunflower	Marigold	Canada Thistle
Untreated Control	48.2 a	22.1 b	8.2 c
Silwet w/o PST	48.6 a	21.9 b	7.8 c
Fresh PST*	22.9 b	10.0 c	7.1 c
Freezer PST*	30.0 b	8.6 c	8.8 c

*Foliar application using airbrush and Silwet L77 at 0.15% (v/v) as formulation

Table 12b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using 3 inoculation methods. (Expt 2)

	Asteraceae Indicator Plants								
Inoculation	Sunflower			Marigold			Canada Thistle		
Methods	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Silwet w/o PST	0	0	0	0	0	0	0	0	0
Fresh PST*	2.25	3	3.25	2.25	3.5	4.25	2	2.75	2.5
Freezer PST*	2	2.75	3	2.25	3.25	4	1.5	2	1.75

*Foliar application using airbrush and Silwet L77 at 0.15% (v/v) as formulation

Table 13a. Effect of Inoculum concentration of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, Canada thistle). (Expt 1)

	Asteraceae Indicator Plants		
Inoculum Concentration*	Sunflower	Marigold	Canada Thistle
Untreated Control	91.0 a	23.7 d	10.4 e
Silwet Blank (0 PST)**	83.2 ab	20.6 d	12.6 e
1 X PST**	56.7 c	4.9 e	10.3 e
0.1 X PST**	75.3 b	5.6 e	10.0 e

* PST concentration based on 10^8 bacteria/ml
**Foliar application using airbrush and Silwet L77 at 0.2% (v/v) as formulation

Table 13b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using different inoculum concentrations. (Expt 1)

	Asteraceae Indicator Plants								
Inoculum	Sunflower			Marigold			Canada Thistle		
Concentration*	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Silwet Blank (0 PST)	0.75	0	0	1	0.25	0	0.75	0.25	0
1 X PST**	1.75	1.75	0.5	3.25	4	4	1.75	1.25	0.5
0.1 X PST*	1.25	1.5	0.25	3.25	4	4	1.75	2	0.5

* PST concentration based on 10^8 bacteria/ml
**Foliar application using airbrush and Silwet L77 at 0.2% (v/v) as formulation

Table 14a. Effect of Inoculum concentration of *Pseudomonas syringae* pv. *tagetis* (PST) on Fresh Weight (g) of Asteraceae plants (Sunflower, Marigold, Canada thistle). (Expt 2)

	Asteraceae Indicator Plants		
Inoculum Concentration*	Sunflower	Marigold	Canada Thistle
Untreated Control	79.9 a	26.4 c	14.8 cd
Silwet Blank (0 PST)**	71.9 a	25.8 c	11.0 d
2 X PST**	45.7 b	9.8 d	11.1 d
1 X PST**	26.9 c	12.4 d	9.7 d
0.5 X PST**	42.0 b	6.9 d	9.9 d

* PST concentration based on 10^8 bacteria/ml
**Foliar application using airbrush and Silwet L77 at 0.2% (v/v) as formulation

Table 14b. Disease symptoms on Asteraceae plants (Sunflower, Marigold, and Canada thistle) caused by *Pseudomonas syringae* pv. *tagetis* (PST) 1, 2, and 3 weeks after inoculating using different inoculum concentrations. (Expt 2)

	Asteraceae Indicator Plants								
Inoculum	Sunflower			Marigold			Canada Thistle		
Concentration*	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0	0	0	0
Silwet Blank (0 PST)	0	0.33	0	0.33	1	0	0.67	0.33	0.33
2 X PST	2	2	2.33	2.67	3.33	3.33	1.33	1	1
1 X PST**	2.67	3	3	2.33	3	3	1.67	1	1
0.5 X PST*	2.33	2.33	2.33	2.33	4	4	1.67	1.67	1

* PST concentration based on 10^8 bacteria/ml

**Foliar application using airbrush and Silwet L77 at 0.2% (v/v) as formulation

Table 15a. Effect of Bacterial Strains on Fresh Weight (g) of Asteraceae plants (Sunflower and Canada thistle).

	Asteraceae Indicator Plants	
Bacterial Strains	Sunflower	Canada Thistle
Untreated Control	88.1 a	9.4 a
Silwet Blank (0 Bacteria)	76.6 ab	8.7 a
VA02-14	73.7 bc	8.9 a
FE02-6	69.8 bcd	8.0 a
FE02-9	69.2 bcd	9.4 a
FE02-7	68.1 bcd	9.1 a
WE02-21	67.6 bcd	8.3 a
FE02-10	65.4 bcd	9.2 a
VA02-22	65.3 bcd	8.4 a
WE02-1	64.4 bcd	8.8 a
FE02-5	63.6 bcd	8.1 a
FE02-8	62.1 cd	9.0 a
WE02-3	58.4 d	8.5 a
PST	40.0 e	7.5 a

*Foliar application with Airbrush using Silwet L77 at 0.2% (v/v) as a Formulation

Table 15b. Disease symptoms on Asteraceae plants (Sunflower and Canada thistle) caused by various Bacterial Strains 1, 2, and 3 weeks after inoculating.

	Asteraceae Indicator Plants					
Bacterial	Sunflower			Canada Thistle		
Strains	wk 1	wk 2	wk 3	wk 1	wk 2	wk 3
Untreated Control	0	0	0	0	0	0
Silwet Blank (0 Bacteria)	0.25	0.25	0.38	0.43	0.43	0.14
VA02-14	0.13	0.13	0.25	0.43	0.43	0.14
FE02-6	0.25	0.25	0.5	0.57	0.43	0.29
FE02-9	0.13	0.13	0.25	1	0.86	0.29
FE02-7	0.13	0.25	0.63	0.57	0.43	0.14
WE02-21	0.25	0.13	0.13	0.57	0.57	0.14
FE02-10	0.38	0.38	0.5	0.71	0.71	0.57
VA02-22	0.25	0	0.38	0.57	0.43	0.71
WE02-1	0.13	0	0.25	0.57	0.57	0
FE02-5	0.25	0.25	0.75	0.71	0.57	0.71
FE02-8	0.13	0.13	0.38	0.43	0.43	0.43
WE02-3	0.38	0.13	0.38	0.14	0.14	0.29
PST	2.25	2.25	2.5	2.14	2	2

*Foliar application with Airbrush using Silwet L77 at 0.2% (v/v) as a Formulation

APPENDIX A1. List of Bacterial strains (isolated and purified) and tested using Callus tissue culture method

Isolate	Collection Site	Rating
02-8A1	Kamsack, SK	4
02-8A2	Kamsack, SK	5
02-8A3	Kamsack, SK	5
02-8A5	Kamsack, SK	5
02-8A7	Kamsack, SK	4.6
02-8A9	Kamsack, SK	5
02-8A10	Kamsack, SK	4.4
02-8B1	Kamsack, SK	4
02-8B2	Kamsack, SK	5
02-8B3	Kamsack, SK	4
02-8B4	Kamsack, SK	4.3
02-8B5	Kamsack, SK	5
02-8B6	Kamsack, SK	4.4
02-8B7	Kamsack, SK	4.4
02-8B8	Kamsack, SK	5
02-8B10	Kamsack, SK	5
02-8B11	Kamsack, SK	4.1
02-8B12	Kamsack, SK	5
02-8B15	Kamsack, SK	4.1
02-8C1	Kamsack, SK	4.3
02-8C4	Kamsack, SK	2.7
02-8C16	Kamsack, SK	4.2
02-8C17	Kamsack, SK	4.6
02-8C19	Kamsack, SK	3.7
02-8C20	Kamsack, SK	3.4
02-8C21	Kamsack, SK	4.3
02-8D13	Kamsack, SK	3.4
96-5Su4-1-C25-I1	Saskatoon, SK	4.3
96-5Su5-1-C20	Saskatoon, SK	5
96-5-Su6-1-C10	Saskatoon, SK	4
96-3-Su6-1-C25	Saskatoon, SK	5
96-3-Su6-1-C23T3	Saskatoon, SK	4
96-3-Su6-2-C10	Saskatoon, SK	5
96-3-Su6-2-C10-T2	Saskatoon, SK	5
96-5-Su4-1-C22#1	Saskatoon, SK	5
96-5-Su6-1-C5-1	Saskatoon, SK	5
96-5-Su6-1-C5#2?	Saskatoon, SK	5
96-5-Su6-1-C6	Saskatoon, SK	5
96-5-Su6-1-C6I2	Saskatoon, SK	5
96-3-Su6-C10-1-T1	Saskatoon, SK	5
96-3-Su6-1-C23-T2	Saskatoon, SK	5
98-75CT2	Saskatoon, SK	4.3
98-75CT3	Saskatoon, SK	5
98-75CT4	Saskatoon, SK	5
98-75CT6	Saskatoon, SK	4
98-75CT7	Saskatoon, SK	5
98-75CT8	Saskatoon, SK	4
CTB12	Saskatoon, SK	5

CT99-33(19)R	Langham, SK	5
CT99-34A(2)R	Saskatoon, SK	4
CT99-39(8)	Kindersley, SK	4.6
CT99-40(9)	Eston, SK	5
CT00-13E2	Hafford, SK	4
CT00-22R-2	Colonsay, SK	5
CT99-31(7)E	Langham, SK	3.3
CT99-35(5)	Rosetown, SK	2
CT99-39(02)	Kindersley, SK	3.3
CT00-SD1-3C	?	2
CT00-23R5	Elstow, SK	1.6
CT99-26(3)R	Radisson, SK	0
CT99-33(14)R	Langham,SK	0
CT99-41(69)	White Bear, SK	0
CT00-135R-05	Meacham, SK	0
CT00-142R88	Allan, SK	0
PST	Minnesota, US	3.8
01-3D7	?	3.6
CT2	Saskatoon, SK	4
CT4	Saskatoon, SK	5
CT5	Saskatoon, SK	5
CT7	Saskatoon, SK	5
BRG100	Oyen, AB	3.6
BRG168	Oyen, AB	4.6
OY4GFT9	Oyen, AB	4
189	Maple Creek, SK	5
C9P(1)0019	?	4
CUDGFT2	Cudworth, SK	5
LIMAF4	Limerick, SK	5
CTB10	Saskatoon, SK	5
CTB1	Saskatoon, SK	4
CTB2	Saskatoon, SK	4
CTB3	Saskatoon, SK	3.3
CTB4	Saskatoon, SK	3.6
CTB5	Saskatoon, SK	4
CTB6	Saskatoon, SK	3.6
CTB7	Saskatoon, SK	4
01-3D2	?	4
01-3D8	?	5
CTB12	Saskatoon, SK	4
VA02-1	Valais, Switzerland	3.6
VA02-2	Valais, Switzerland	3
VA02-3	Valais, Switzerland	2.6
VA02-4	Valais, Switzerland	4.6
VA02-5	Valais, Switzerland	3
VA02-9	Valais, Switzerland	3
VA02-10	Valais, Switzerland	5
VA02-11	Valais, Switzerland	4
VA02-13	Valais, Switzerland	3
VA02-14	Valais, Switzerland	4.3
VA02-15	Valais, Switzerland	5
VA02-16	Valais, Switzerland	4.3
VA02-17	Valais, Switzerland	4

VA02-18	Valais, Switzerland	3
VA02-19	Valais, Switzerland	5
VA02-20	Valais, Switzerland	3
VA02-21	Valais, Switzerland	4
VA02-22	Valais, Switzerland	4
WE02-1	Weinstetten, Germany	4
WE02-2	Weinstetten, Germany	0
WE02-3	Weinstetten, Germany	5
WE02-4	Weinstetten, Germany	3
WE02-5	Weinstetten, Germany	4
WE02-6	Weinstetten, Germany	4
WE02-7	Weinstetten, Germany	4
WE02-8	Weinstetten, Germany	4
WE02-9	Weinstetten, Germany	4.3
WE02-10	Weinstetten, Germany	3
WE02-11	Weinstetten, Germany	2
WE02-12	Weinstetten, Germany	4
WE02-13	Weinstetten, Germany	2
WE02-14	Weinstetten, Germany	2
WE02-15	Weinstetten, Germany	1
WE02-16	Weinstetten, Germany	0.3
WE02-17	Weinstetten, Germany	1
WE02-18	Weinstetten, Germany	5
WE02-19	Weinstetten, Germany	5
WE02-20	Weinstetten, Germany	0
WE02-21	Weinstetten, Germany	5
WE02-22	Weinstetten, Germany	5
FE02-1	Fessenheim, France	2.6
FE02-2	Fessenheim, France	0
FE02-3	Fessenheim, France	2.6
FE02-4	Fessenheim, France	0
FE02-5	Fessenheim, France	5
FE02-6	Fessenheim, France	5
FE02-7	Fessenheim, France	4.3
FE02-8	Fessenheim, France	5
FE02-9	Fessenheim, France	4.3
FE02-10	Fessenheim, France	3.6
03-1A1	Holbein, SK	5
03-1A2	Holbein, SK	5
03-1A3	Holbein, SK	4
03-1A6	Holbein, SK	3.6
03-1A12	Holbein, SK	5
03-1B6	Holbein, SK	3.6
03-4A1	Shellbrook, SK	5
03-10C	Saskatoon, SK	5
03-11A1	Saskatoon, SK	4
03-11A6	Saskatoon, SK	5
03-11B1	Saskatoon, SK	5
03-11B2	Saskatoon, SK	4
03-11B3	Saskatoon, SK	4
03-11B4	Saskatoon, SK	5
03-11B6	Saskatoon, SK	4
03-11B8	Saskatoon, SK	4
03011B9	Saskatoon, SK	5

APPENDIX A2. List of Bacterial strains collected, isolated, purified, and screened

Bacterial Strain - CODE	Collection site
96-5-Su6-1-C5#2	Saskatoon, SK
96-5-Su6-1-C6I2	Saskatoon, SK
98-75CT3	Saskatoon, SK
98-75CT4	Saskatoon, SK
98-75CT7	Saskatoon, SK
CTB12	Saskatoon, SK
WRE-03-1	Werther, Germany
WRE-03-6	Werther, Germany
WRE-03-9	Werther, Germany
WRE-03-10	Werther, Germany
WRE-03-12	Werther, Germany
WRE-03-14	Werther, Germany
WRE-03-18	Werther, Germany
WRE-03-19	Werther, Germany
UH1-03-2	Uchte 1, Germany
UH1-03-6	Uchte 1, Germany
UH1-03-8	Uchte 1, Germany
UH2-03-3	Uchte 2, Germany
UH2-03-5	Uchte 2, Germany
UH2-03-6	Uchte 2, Germany
UH2-03-10	Uchte 2, Germany
UH2-03-13	Uchte 2, Germany
UH2-03-14	Uchte 2, Germany
UH2-03-15	Uchte 2, Germany
BIELF3-03-1	Bielefeld 3 - Brake, Germany
BIELF3-03-6	Bielefeld 3 - Brake, Germany
BIELF3-03-8	Bielefeld 3 - Brake, Germany
BIELF3-03-10	Bielefeld 3 - Brake, Germany
BIELF3-03-15	Bielefeld 3 - Brake, Germany
BIELF1-03-1	Bielefeld 1, Germany
BIELF1-03-6	Bielefeld 1, Germany
BIELF1-03-8	Bielefeld 1, Germany
BIELF1-03-10	Bielefeld 1, Germany
BIELF1-03-12	Bielefeld 1, Germany
BIELF2-03-5	Bielefeld 2 - Uni, Germany
BIELF2-03-7	Bielefeld 2 - Uni, Germany
BIELF2-03-1	Bielefeld 2 - Uni, Germany
SIO2-03-1	Sion 1, Switzerland
SIO2-03-3	Sion 1, Switzerland
SIO1-03-9	Sion 2, Switzerland
SIO1-03-4	Sion 2, Switzerland
SIO1-03-6	Sion 2, Switzerland
SIE2-03-4	Sierre 2 - km 338, Switzerland
SIE2-03-1	Sierre 2 - km 338, Switzerland
SIE1-03-5	Sierre 1 - km 337, Switzerland
SIE1-03-1	Sierre 1 - km 337, Switzerland
SIE1-03-4	Sierre 1 - km 337, Switzerland
SIE1-03-7	Sierre 1 - km 337, Switzerland

FR-03-4	Besancon, France
FR-03-2	Besancon, France
GOT-03-3	Gottingen, Germany
GOT-03-6	Gottingen, Germany
GOT-03-9	Gottingen, Germany
GOT-03-12	Gottingen, Germany
KIR-03-1	Kirchlengen, Germany
ESP-03-3	Espelkamp, Germany
ESP-03-4	Espelkamp, Germany
ESP-03-7	Espelkamp, Germany
Z1-03-1	Zienken 1, Germany
Z1-03-4	Zienken 1, Germany
Z2-03-1	Zienken 2, Germany
Z2-03-3	Zienken 2, Germany
DOB1-03-1	Dobanovci - Rampa, Serbia
DOB1-03-4	Dobanovci - Rampa, Serbia
DOB2-03-1	Dobanovic
DOB2-03-5	Dobanovic
DOB2-03-8	Dobanovic
DOB2-03-9	Dobanovic
DOB2-03-11	Dobanovic
URC1-03-1	Urcin 1 - Salas
URC1-03-2	Urcin 1 - Salas
URC1-03-4	Urcin 1 - Salas
URC2-03-2	Urcin 2 - Rampa
URC2-03-3	Urcin 2 - Rampa
URC2-03-6	Urcin 2 - Rampa
URC2-03-7	Urcin 2 - Rampa
URC3-03-1	Urcin 3 - Odmoriste, Serbia
URC3-03-2	Urcin 3 - Odmoriste, Serbia
URC3-03-3	Urcin 3 - Odmoriste, Serbia
URC3-03-5	Urcin 3 - Odmoriste, Serbia
URC4-03-1	Urcin 4 - Mladenovac, Serbia
URC4-03-3	Urcin 4 - Mladenovac, Serbia
URC4-03-5	Urcin 4 - Mladenovac, Serbia
UGR-03-1	Ugtinovci, Serbia
UGR-03-3	Ugtinovci, Serbia
UGR-03-5	Ugtinovci, Serbia
UGR-03-6	Ugtinovci, Serbia
UNP-03-1	Unpinovo Obetsva Bara, Serbia
UNP-03-3	Unpinovo Obetsva Bara, Serbia
UNP-03-5	Unpinovo Obetsva Bara, Serbia

APPENDIX B. Sboot length measurements from root dip/soil drench and wounding inoculation experiments.

Table 1: Means of total shoot length (mm) for each isolate at 2. 4 and 6 weeks – root dip and drench experiments.

Isolate	Shoot Length Mean (2 wks)	Shoot length Mean (4 wks)	Shoot Length Mean (6 wks)
Control	36.00	72.00	80.1
Pst-EB056	47.25	69.88	91.88
VA02-22	47.00	80	109.25
Control	53.33	91.67	95.00
VA02-1	48.75	102.50	110.00
VA02-2	48.75	86.25	95.00
VA02-3	55.00	88.75	91.25
VA02-4	70.00	110.00	128.75
Pst-EB056	56.25	92.50	92.50
Control	70.00	102.00	104.00
VA02-5	50.00	93.00	103.00
VA02-9	65.00	93.00	99.00
VA02-10	82.00	90.00	95.00
VA02-11	80.00	101.00	116.00
VA02-13	52.00	92.00	105.00
Control	65.00	135.00	153.00
VA02-14	60.00	160.00	174.00
VA02-15	51.00	120.00	149.00
VA02-16	72.00	170.00	181.00
VA02-17	59.00	142.00	159.00
Control	78.00	140.00	179.00
VA02-18	50.00	113.00	152.00
VA02-19	59.00	125.00	161.00
VA02-20	72.00	109.00	135.00
VA02-21	89.00	145.00	171.00
Control	90.00	150.00	186.00
WE02-1	86.00	154.00	175.00
WE02-2	89.00	152.00	182.00
WE02-3	86.00	160.00	184.00
WE02-4	82.00	164.00	180.00
WE02-5	72.00	153.00	173.00

Control	65.00	129.00	161.00
WE02-6	61.00	148.00	177.00
WE02-7	63.00	150.00	161.00
WE02-8	57.00	119.00	143.00
WE02-9	69.00	149.00	164.00
WE02-10	69.00	141.00	182.00
Control	39.00	89.00	109.00
WE02-11	49.00	114.00	143.00
WE02-12	41.00	92.00	114.00
WE02-13	44.00	90.00	109.00
WE02-14	37.00	82.00	105.00
PstEB056	34.00	80.00	90.00
Control	44.00	87.00	109.00
WE02-15	49.00	105.00	122.00
WE02-16	42.00	96.00	110.00
WE02-17	55.00	103.00	119.00
WE02-18	44.00	87.00	110.00
WE02-19	58.00	108.00	124.00
Control	33.00	78.00	87.00
WE02-20	38.00	87.00	92.00
WE02-21	54.00	119.00	135.00
WE02-22	38.00	93.00	117.00
FE02-1	37.50	75.00	83.75
FE02-2	45.00	100.00	112.00
Control	50.00	129.00	156.00
FE02-3	72.00	148.00	174.00
FE02-4	79.00	192.00	194.00
FE02-5	81.00	150.00	172.00
FE02-6	80.00	148.00	161.00
Control	61.00	124.00	197.00
FE02-7	86.00	156.00	196.00
FE02-8	81.00	134.00	180.00
FE02-9	78.00	185.00	228.00
FE02-10	82.00	142.00	195.00

Table 2: Means of total shoot length (mm) for each isolate at 2, 4 and 6 weeks – wounding inoculation experiments.

Isolate	Shoot Length Mean (2 wks)	Shoot length Mean (4 wks)	Shoot Length Mean (6 wks)
NB CTL	102.00	117.00	135.00
VA02-1	87.00	103.00	115.00
VA02-2	87.00	95.00	105.00
VA02-3	95.00	105.00	106.00
VA02-4	93.00	121.00	132.00
NB CTL	69.00	86.00	109.00
VA02-18	80.00	96.00	109.00
VA02-19	64.00	86.00	88.00
VA02-20	78.00	95.00	110.00
VA02-21	80.00	89.00	98.00
NB CTL	91.00	112.00	111.00
WE02-1	82.00	92.00	93.00
WE02-2	81.00	87.00	87.00
WE02-3	80.00	82.00	88.00
WE02-4	92.00	102.00	103.00
NB CTL	105.00	120.00	126.00
WE02-6	112.00	126.00	122.00
WE02-7	112.00	136.00	133.00
WE02-8	110.00	133.00	137.00
WE02-9	97.00	118.00	122.00
WE02-10		137.00	141.00
NB CTL	120.00	130.00	131.00
WE02-11	102.00	126.00	129.00
WE02-12	109.00	127.00	141.00
PstEB056	91.00	116.00	119.00
VA02-14	114.00	128.00	127.00
VA02-15	99.00	100.00	97.00
NB CTL	111.00	126.00	133.00
WE02-15	99.00	116.00	117.00
WE02-16	102.00	124.00	120.00
WE02-17	101.00	122.00	126.00
WE02-18	112.00	129.00	125.00
WE02-19	96.00	116.00	115.00

NB CTL	93.00	111.00	115.00
WE02-20	101.00	126.00	142.00
WE02-21	100.00	126.00	125.00
WE02-22	110.00	131.00	141.00
FE02-1	109.00	124.00	131.00
FE02-2	99.00	124.00	123.00

Control	96.00	113.00	119.00
FE02-3	88.00	109.00	107.00
FE02-4	88.00	109.00	115.00
FE02-5	91.00	118.00	119.00
FE02-6	85.00	98.00	99.00

Control	83.00	116.00	128.00
VA02-5	98.00	117.00	127.00
VA02-9	89.00	129.00	134.00
VA02-10	84.00	113.00	109.00
VA02-11	84.00	119.00	121.00
VA02-13	75.00	111.00	121.00

Control	95.00	109.00	113.00
FE02-7	107.00	116.00	116.00
FE02-8	112.00	121.00	121.00
FE02-9	97.00	118.00	118.00
FE02-10	89.00	118.00	118.00

Control	68.00	87.00	95.00
VA02-16	78.00	120.00	128.00
VA02-17	78.00	113.00	102.00
VA02-22	116.00	147.00	141.00
WEO2-5	98.00	132.00	136.00
WE02-13	67.00	86.00	101.00
WE02-14	90.00	131.00	136.00